REPORT

OF THE

SEVENTY-FIRST MEETING

OF THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE

HELD AT

GLASGOW IN SEPTEMBER 1901.

LONDON:
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PLATE

OBJECTS AND RULES

OF

THE ASSOCIATION.

OBJECTS.

THE ASSOCIATION contemplates no interference with the ground occupied by other institutions. Its objects are:—To give a stronger impulse and a more systematic direction to scientific inquiry,—to promote the intercourse of those who cultivate Science in different parts of the British Empire, with one another and with foreign philosophers,—to obtain a more general attention to the objects of Science, and a removal of any disadvantages of a public kind which impede its progress.

RULES.

Admission of Members and Associates.

All persons who have attended the first Meeting shall be entitled to become Members of the Association, upon subscribing an obligation to conform to its Rules.

The Fellows and Members of Chartered Literary and Philosophical Societies publishing Transactions, in the British Empire, shall be entitled, in like manner, to become Members of the Association.

The Officers and Members of the Councils, or Managing Committees, of Philosophical Institutions shall be entitled, in like manner, to become Members of the Association.

All Members of a Philosophical Institution recommended by its Council or Managing Committee shall be entitled, in like manner, to become Members of the Association.

Persons not belonging to such Institutions shall be elected by the General Committee or Council to become Life Members of the Association, Annual Subscribers, or Associates for the year, subject to the approval of a General Meeting.

Compositions, Subscriptions, and Privileges.

LIFE MEMBERS shall pay, on admission, the sum of Ten Pounds. They shall receive *gratuitously* the Reports of the Association which may be published after the date of such payment. They are eligible to all the offices of the Association.

ANNUAL SUBSCRIBERS shall pay, on admission, the sum of Two Pounds, and in each following year the sum of One Pound. They shall receive

gratuitously the Reports of the Association for the year of their admission and for the years in which they continue to pay *without intermission* their Annual Subscription. By omitting to pay this subscription in any particular year, Members of this class (Annual Subscribers) *lose for that and all future years* the privilege of receiving the volumes of the Association *gratis;* but they may resume their Membership and other privileges at any subsequent Meeting of the Association, paying on each such occasion the sum of One Pound. They are eligible to all the offices of the Association.

ASSOCIATES for the year shall pay on admission the sum of One Pound. They shall not receive *gratuitously* the Reports of the Association, nor be eligible to serve on Committees, or to hold any office.

The Association consists of the following classes:—

1. Life Members admitted from 1831 to 1845 inclusive, who have paid on admission Five Pounds as a composition.
2. Life Members who in 1846, or in subsequent years, have paid on admission Ten Pounds as a composition.
3. Annual Members admitted from 1831 to 1839 inclusive, subject to the payment of One Pound annually. [May resume their Membership after intermission of Annual Payment.]
4. Annual Members admitted in any year since 1839, subject to the payment of Two Pounds for the first year, and One Pound in each following year. [May resume their Membership after intermission of Annual Payment.]
5. Associates for the year, subject to the payment of One Pound.
6. Corresponding Members nominated by the Council.

And the Members and Associates will be entitled to receive the annual volume of Reports, *gratis*, or to *purchase* it at reduced (or Members') price, according to the following specification, viz.:—

1. *Gratis.*—Old Life Members who have paid Five Pounds as a composition for Annual Payments, and previous to 1845 a further sum of Two Pounds as a Book Subscription, or, since 1845, a further sum of Five Pounds.

   New Life Members who have paid Ten Pounds as a composition.

   Annual Members *who have not intermitted* their Annual Subscription.

2. *At reduced or Members' Price*, viz., two-thirds of the Publication Price. —Old Life Members who have paid Five Pounds as a composition for Annual Payments, but no further sum as a Book Subscription.

   Annual Members who have intermitted their Annual Subscription.

   Associates for the year. [Privilege confined to the volume for that year only.]

3. Members may purchase (for the purpose of completing their sets) any of the volumes of the Reports of the Association up to 1874, *of which more than* 15 *copies remain*, at 2*s*. 6*d*. per volume.[1]

Application to be made at the Office of the Association.

Volumes not claimed within two years of the date of publication can only be issued by direction of the Council.

Subscriptions shall be received by the Treasurer or Secretaries.

[1] A few complete sets, 1831 to 1874, are on sale, at £10 the set.

Meetings.

The Association shall meet annually, for one week, or longer. The place of each Meeting shall be appointed by the General Committee not less than two years in advance [1]; and the arrangements for it shall be entrusted to the Officers of the Association.

General Committee.

The General Committee shall sit during the week of the Meeting, or longer, to transact the business of the Association. It shall consist of the following persons:—

CLASS A. PERMANENT MEMBERS.

1. Members of the Council, Presidents of the Association, and Presidents of Sections for the present and preceding years, with Authors of Reports in the Transactions of the Association.

2. Members who by the publication of Works or Papers have furthered the advancement of those subjects which are taken into consideration at the Sectional Meetings of the Association. *With a view of submitting new claims under this Rule to the decision of the Council, they must be sent to the Assistant General Secretary at least one month before the Meeting of the Association. The decision of the Council on the claims of any Member of the Association to be placed on the list of the General Committee to be final.*

CLASS B. TEMPORARY MEMBERS.[2]

1. Delegates nominated by the Corresponding Societies under the conditions hereinafter explained. *Claims under this Rule to be sent to the Assistant General Secretary before the opening of the Meeting.*

2. Office-bearers for the time being, or delegates, altogether not exceeding three, from Scientific Institutions established in the place of Meeting. *Claims under this Rule to be approved by the Local Secretaries before the opening of the Meeting.*

3. Foreigners and other individuals whose assistance is desired, and who are specially nominated in writing, for the Meeting of the year, by the President and General Secretaries.

4. Vice-Presidents and Secretaries of Sections.

Organising Sectional Committees.[3]

The Presidents, Vice-Presidents, and Secretaries of the several Sections are nominated by the Council, and have power to exercise the functions of Sectional Committees until their names are submitted to the General Committee for election.

From the time of their nomination they constitute Organising Committees for the purpose of obtaining information upon the Memoirs and Reports likely to be submitted to the Sections,[4] and of preparing Reports

[1] Revised by the General Committee, Liverpool, 1896.

[2] Revised, Montreal, 1884.

[3] Passed, Edinburgh, 1871, revised, Dover, 1899.

[4] *Notice to Contributors of Memoirs.*—Authors are reminded that, under an arrangement dating from 1871, the acceptance of Memoirs, and the days on which

thereon, and on the order in which it is desirable that they should be read. The Sectional Presidents of former years are *ex officio* members of the Organising Sectional Committees.[1]

An Organising Committee may also hold such preliminary meetings as the President of the Committee thinks expedient, but shall, under any circumstances, meet on the first Wednesday of the Annual Meeting, at 2 P.M., to appoint members of the Sectional Committee.[2]

Constitution of the Sectional Committees.[3]

On the first day of the Annual Meeting, the President, Vice-Presidents, and Secretaries of each Section, who will be appointed by the General Committee at 4 P.M., and those previous Presidents and Vice-Presidents of the Section who may desire to attend, are to meet, at 2 P.M., in their Committee Rooms, and appoint the Sectional Committees by selecting individuals from among the Members (not Associates) present at the Meeting whose assistance they may particularly desire. Any Member who has intimated the intention of attending the Meeting, and who has already served upon a Committee of a Section, is eligible for election as a Member of the Committee of that Section at its first meeting.[4] The Sectional Committees thus constituted shall have power to add to their number from day to day.

The List thus formed is to be entered daily in the Sectional Minute-Book, and a copy forwarded without delay to the Printer, who is charged with publishing the same before 8 A.M. on the next day in the Journal of the Sectional Proceedings.

Business of the Sectional Committees.

Committee Meetings are to be held on the Wednesday, and on the following Thursday, Friday, Saturday,[5] Monday, and Tuesday, for the objects stated in the Rules of the Association. The Organising Committee of a Section is empowered to arrange the hours of meeting of the Section and the Sectional Committee except for Saturday.[6]

The business is to be conducted in the following manner:—

1. The President shall call on the Secretary to read the minutes of the previous Meeting of the Committee.

they are to be read, are now as far as possible determined by Organising Committees for the several Sections *before the beginning of the Meeting*. It has therefore become necessary, in order to give an opportunity to the Committees of doing justice to the several Communications, that each author should prepare an Abstract of his Memoir of a length suitable for insertion in the published Transactions of the Association, and that he should send it, together with the original Memoir, by book-post, on or before........................., addressed to the General Secretaries, at the office of the Association. 'For Section.........' If it should be inconvenient to the Author that his paper should be read on any particular days, he is requested to send information thereof to the Secretaries in a separate note. Authors who send in their MSS. three complete weeks before the Meeting, and whose papers are accepted, will be furnished, before the Meeting, with printed copies of their Reports and abstracts. No Report, Paper, or Abstract can be inserted in the Annual Volume unless it is handed either to the Recorder of the Section or to the Assistant General Secretary *before the conclusion of the Meeting*.

[1] Sheffield, 1879. [2] Swansea, 1880, revised, Dover, 1899.

[3] Edinburgh, 1871, revised, Dover, 1899. [4] Glasgow, 1901.

[5] The meeting on Saturday is optional, Southport, 1883. [6] Nottingham, 1893.

2. No paper shall be read until it has been formally accepted by the Committee of the Section, and entered on the minutes accordingly.
3. Papers which have been reported on unfavourably by the Organising Committees shall not be brought before the Sectional Committees.[1]

At the first meeting, one of the Secretaries will read the Minutes of last year's proceedings, as recorded in the Minute-Book, and the Synopsis of Recommendations adopted at the last Meeting of the Association and printed in the last volume of the Report. He will next proceed to read the Report of the Organising Committee.[2] The list of Communications to be read on Thursday shall be then arranged, and the general distribution of business throughout the week shall be provisionally appointed.[2] At the close of the Committee Meeting the Secretaries shall forward to the Printer a List of the Papers appointed to be read. The Printer is charged with publishing the same before 8 A.M. on Thursday in the Journal.

On the second day of the Annual Meeting, and the following days, the Secretaries are to correct, on a copy of the Journal, the list of papers which have been read on that day, to add to it a list of those appointed to be read on the next day, and to send this copy of the Journal as early in the day as possible to the Printer, who is charged with printing the same before 8 A.M. next morning in the Journal. It is necessary that one of the Secretaries of each Section (generally the Recorder) should call at the Printing Office and revise the proof each evening.

Minutes of the proceedings of every Committee are to be entered daily in the Minute-Book, which should be confirmed at the next meeting of the Committee.

Lists of the Reports and Memoirs read in the Sections are to be entered in the Minute-Book daily, which, with *all Memoirs and Copies or Abstracts of Memoirs furnished by Authors, are to be forwarded, at the close of the Sectional Meetings*, to the Assistant General Secretary.

The Vice-Presidents and Secretaries of Sections become *ex officio* temporary Members of the General Committee (*vide* p. xxxi), and will receive, on application to the Treasurer in the Reception Room, Tickets entitling them to attend its Meetings.

The Committees will take into consideration any suggestions which may be offered by their Members for the advancement of Science. They are specially requested to review the recommendations adopted at preceding Meetings, as published in the volumes of the Association, and the communications made to the Sections at this Meeting, for the purposes of selecting definite points of research to which individual or combined exertion may be usefully directed, and branches of knowledge on the state and progress of which Reports are wanted; to name individuals or Committees for the execution of such Reports or researches; and to state whether, and to what degree, these objects may be usefully advanced by the appropriation of the funds of the Association, by application to Government, Philosophical Institutions, or Local Authorities.

In case of appointment of Committees for special objects of Science, it is expedient that *all Members of the Committee should be named, and*

[1] Plymouth, 1877. [2] Edinburgh, 1871.

one of them appointed to act as Chairman, who shall have notified personally or in writing his willingness to accept the office, the Chairman to have the responsibility of receiving and disbursing the grant (if any has been made) and securing the presentation of the Report in due time; and, further, it is expedient that one of the members should be appointed to act as Secretary, for ensuring attention to business.

That it is desirable that the number of Members appointed to serve on a Committee should be as small as is consistent with its efficient working.

That a tabular list of the Committees appointed on the recommendation of each Section should be sent each year to the Recorders of the several Sections, to enable them to fill in the statement whether the several Committees appointed on the recommendation of their respective Sections had presented their reports.

That on the proposal to recommend the appointment of a Committee for a special object of science having been adopted by the Sectional Committee, the number of Members of such Committee be then fixed, but that the Members to serve on such Committee be nominated and selected by the Sectional Committee at a subsequent meeting.[1]

Committees have power to add to their number persons whose assistance they may require.

The recommendations adopted by the Committees of Sections are to be registered in the Forms furnished to their Secretaries, and one Copy of each is to be forwarded, without delay, to the Assistant General Secretary for presentation to the Committee of Recommendations. *Unless this be done, the Recommendations cannot receive the sanction of the Association.*

N.B.—Recommendations which may originate in any one of the Sections must *first be sanctioned by the Committee of that Section* before they can be referred to the Committee of Recommendations or confirmed by the General Committee.

Notices regarding Grants of Money.[2]

1. No Committee shall raise money in the name or under the auspices of the British Association without special permission from the General Committee to do so; and no money so raised shall be expended except in accordance with the Rules of the Association.
2. In grants of money to Committees the Association does not contemplate the payment of personal expenses to the Members.
3. Committees to which grants of money are entrusted by the Association for the prosecution of particular Researches in Science are appointed for one year only. If the work of a Committee cannot be completed in the year, and if the Sectional Committee desire the work to be continued, application for the reappointment of the Committee for another year must be made at the next meeting of the Association.
4. Each Committee is required to present a Report, whether final or interim, at the next meeting of the Association after their appointment or reappointment. Interim Reports must be submitted in writing, though not necessarily for publication.

[1] Revised by the General Committee, Bath, 1888.
[2] Revised by the General Committee at Ipswich, 1895.

5. In each Committee the Chairman is the only person entitled to call on the Treasurer, Professor G. Carey Foster, F.R.S., for such portion of the sums granted as may from time to time be required.
6. Grants of money sanctioned at a meeting of the Association expire on June 30 following. The Treasurer is not authorised after that date to allow any claims on account of such grants.
7. The Chairman of a Committee must, before the meeting of the Association next following after the appointment or reappointment of the Committee, forward to the Treasurer a statement of the sums which have been received and expended, with vouchers. The Chairman must also return the balance of the grant, if any, which has been received and not spent; or, if further expenditure is contemplated, he must apply for leave to retain the balance.
8. When application is made for a Committee to be reappointed, and to retain the balance of a former grant which is in the hands of the Chairman, and also to receive a further grant, the amount of such further grant is to be estimated as being additional to, and not inclusive of, the balance proposed to be retained.
9. The Committees of the Sections shall ascertain whether a Report has been made by every Committee appointed at the previous Meeting to whom a sum of money has been granted, and shall report to the Committee of Recommendations in every case where no such report has been received.
10. Members and Committees who may be entrusted with sums of money for collecting specimens of any description are requested to reserve the specimens so obtained to be dealt with by authority of the Council.
11. Committees are requested to furnish a list of any apparatus which may have been purchased out of a grant made by the Association, and to state whether the apparatus will be useful for continuing the research in question, or for other scientific purposes.
12. All Instruments, Papers, Drawings, and other property of the Association are to be deposited at the Office of the Association when not employed in scientific inquiries for the Association.

Business of the Sections.

The Meeting Room of each Section is opened for conversation shortly before the meeting commences. *The Section Rooms and approaches thereto can be used for no notices, exhibitions, or other purposes than those of the Association.*

At the time appointed the Chair will be taken,[1] and the reading of communications, in the order previously made public, commenced.

Sections may, by the desire of the Committees, divide themselves into Departments, as often as the number and nature of the communications delivered in may render such divisions desirable.

[1] The Organising Committee of a Section is empowered to arrange the hours of meeting of the Section and of the Sectional Committee, except for Saturday.

A Report presented to the Association, and read to the Section which originally called for it, may be read in another Section, at the request of the Officers of that Section, with the consent of the Author.

Duties of the Doorkeepers.

1. To remain constantly at the Doors of the Rooms to which they are appointed during the whole time for which they are engaged.
2. To require of every person desirous of entering the Rooms the exhibition of a Member's, Associate's, or Lady's Ticket, or Reporter's Ticket, signed by the Treasurer, or a Special Ticket signed by the Assistant General Secretary.
3. Persons unprovided with any of these Tickets can only be admitted to any particular Room by order of the Secretary in that Room.

No person is exempt from these Rules, except those Officers of the Association whose names are printed in the Official Programme, p. 1.

Duties of the Messengers.

To remain constantly at the Rooms to which they are appointed during the whole time for which they are engaged, except when employed on messages by one of the Officers directing these Rooms.

Committee of Recommendations.

The General Committee shall appoint at each Meeting a Committee, which shall receive and consider the Recommendations of the Sectional Committees, and report to the General Committee the measures which they would advise to be adopted for the advancement of Science.

The *ex officio* members of the Committee of Recommendations are the President and Vice-Presidents of the Meeting, the General and Assistant-General Secretaries, the General Treasurer, the Trustees, and the Presidents of the Association in former years.

All Recommendations of Grants of Money, Requests for Special Researches, and Reports on Scientific Subjects shall be submitted to the Committee of Recommendations, and not taken into consideration by the General Committee unless previously recommended by the Committee of Recommendations.

All proposals for establishing new Sections, or altering the titles of Sections, or for any other change in the constitutional forms and fundamental rules of the Association, shall be referred to the Committee of Recommendations for a report.[1]

If the President of a Section is unable to attend a meeting of the Committee of Recommendations, the Sectional Committee shall be authorised to appoint a Vice-President, or, failing a Vice-President, some other member of the Committee, to attend in his place, due notice of the appointment being sent to the Assistant General Secretary.[2]

[1] Passed by the General Committee at Birmingham, 1865.
[2] Passed by the General Committee at Leeds, 1890.

Corresponding Societies.[1]

1. Any Society is eligible to be placed on the List of Corresponding Societies of the Association which undertakes local scientific investigations, and publishes notices of the results.

2. Application may be made by any Society to be placed on the List of Corresponding Societies. Applications must be addressed to the Assistant General Secretary on or before the 1st of June preceding the Annual Meeting at which it is intended they should be considered, and must be accompanied by specimens of the publications of the results of the local scientific investigations recently undertaken by the Society.

3. A Corresponding Societies Committee shall be annually nominated by the Council and appointed by the General Committee for the purpose of considering these applications, as well as for that of keeping themselves generally informed of the annual work of the Corresponding Societies, and of superintending the preparation of a list of the papers published by them. This Committee shall make an annual report to the General Committee, and shall suggest such additions or changes in the List of Corresponding Societies as they may think desirable.

4. Every Corresponding Society shall return each year, on or before the 1st of June, to the Assistant General Secretary of the Association, a schedule, properly filled up, which will be issued by him, and which will contain a request for such particulars with regard to the Society as may be required for the information of the Corresponding Societies Committee.

5. There shall be inserted in the Annual Report of the Association a list, in an abbreviated form, of the papers published by the Corresponding Societies during the past twelve months which contain the results of the local scientific work conducted by them; those papers only being included which refer to subjects coming under the cognisance of one or other of the various Sections of the Association.

6. A Corresponding Society shall have the right to nominate any one of its members, who is also a Member of the Association, as its delegate to the Annual Meeting of the Association, who shall be for the time a Member of the General Committee.

Conference of Delegates of Corresponding Societies.

7. The Conference of Delegates of Corresponding Societies is empowered to send recommendations to the Committee of Recommendations for their consideration, and for report to the General Committee.

8. The Delegates of the various Corresponding Societies shall constitute a Conference, of which the Chairman, Vice-Chairmen, and Secretaries shall be annually nominated by the Council, and appointed by the General Committee, and of which the members of the Corresponding Societies Committee shall be *ex officio* members.

9. The Conference of Delegates shall be summoned by the Secretaries to hold one or more meetings during each Annual Meeting of the Association, and shall be empowered to invite any Member or Associate to take part in the meetings.

10. The Secretaries of each Section shall be instructed to transmit to

[1] Passed by the General Committee, 1884.

the Secretaries of the Conference of Delegates copies of any recommendations forwarded by the Presidents of Sections to the Committee of Recommendations bearing upon matters in which the co-operation of Corresponding Societies is desired; and the Secretaries of the Conference of Delegates shall invite the authors of these recommendations to attend the meetings of the Conference and give verbal explanations of their objects and of the precise way in which they would desire to have them carried into effect.

11. It will be the duty of the Delegates to make themselves familiar with the purport of the several recommendations brought before the Conference, in order that they and others who take part in the meetings may be able to bring those recommendations clearly and favourably before their respective Societies. The Conference may also discuss propositions bearing on the promotion of more systematic observation and plans of operation, and of greater uniformity in the mode of publishing results.

Local Committees.

Local Committees shall be formed by the Officers of the Association to assist in making arrangements for the Meetings.

Local Committees shall have the power of adding to their numbers those Members of the Association whose assistance they may desire.

Officers.

A President, two or more Vice-Presidents, one or more Secretaries, and a Treasurer shall be annually appointed by the General Committee.

Council.

In the intervals of the Meetings, the affairs of the Association shall be managed by a Council appointed by the General Committee. The Council may also assemble for the despatch of business during the week of the Meeting.

(1) The Council shall consist of[1]

1. The Trustees.
2. The past Presidents.
3. The President and Vice-Presidents for the time being.
4. The President and Vice-Presidents elect.
5. The past and present General Treasurers, General and Assistant General Secretaries.
6. The Local Treasurer and Secretaries for the ensuing Meeting.
7. Ordinary Members.

(2) The Ordinary Members shall be elected annually from the General Committee.

[1] Passed by the General Committee at Belfast, 1874.

(3) There shall be not more than twenty-five Ordinary Members, of whom not more than twenty shall have served on the Council, as Ordinary Members, in the previous year.

(4) In order to carry out the foregoing rule, the following Ordinary Members of the outgoing Council shall at each annual election be ineligible for nomination:—1st, those who have served on the Council for the greatest number of consecutive years; and, 2nd, those who, being resident in or near London, have attended the fewest number of Meetings during the year —observing (as nearly as possible) the proportion of three by seniority to two by least attendance.

(5) The Council shall submit to the General Committee in their Annual Report the names of the Members of the General Committee whom they recommend for election as Members of Council.

(6) The Election shall take place at the same time as that of the Officers of the Association.

Papers and Communications.

The Author of any paper or communication shall be at liberty to reserve his right of property therein.

Accounts.

The Accounts of the Association shall be audited annually, by Auditors appointed by the General Committee.

Table showing the Places and Times of Meeting of the British Association, with Presidents, Vice-Presidents, and Local Secretaries, from its Commencement.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The EARL FITZWILLIAM, D.C.L., F.R.S., F.G.S., &c. YORK, September 27, 1831.	Rev. W. Vernon Harcourt, M.A., F.R.S., F.G.S.	William Gray, jun., Esq., F.G.S. Professor Phillips, M.A., F.R.S., F.G.S.
The REV. W. BUCKLAND, D.D., F.R.S., F.G.S., &c. OXFORD, June 19, 1832.	Sir David Brewster, F.R.S. L. & E., &c. Rev. W. Whewell F.R.S., Pres. Geol. Soc.	Professor Daubeny, M.D., F.R.S., &c. Rev. Professor Powell, M.A., F.R.S., &c.
The REV. ADAM SEDGWICK, M.A., V.P.R.S., V.P.G.S. CAMBRIDGE, June 25, 1833.	G. B. Airy, Esq., F.R.S., Astronomer Royal, &c. John Dalton, Esq., D.C.L., F.R.S.	Rev. Professor Henslow, M.A., F.L.S., F.G.S. Rev. W. Whewell, F.R.S.
SIR T. MACDOUGALL BRISBANE, K.C.B., D.C.L., F.R.S. L. & E. EDINBURGH, September 8, 1834.	Sir David Brewster, F.R.S., &c. Rev. T. R. Robinson, D.D.	Professor Forbes, F.R.S. L. & E., &c. Sir John Robinson, Sec. R.S.E.
The REV. PROVOST LLOYD, LL.D. DUBLIN, August 10, 1835.	Viscount Oxmantown, F.R.S., F.R.A.S. Rev. W. Whewell, F.R.S., &c.	Sir W. R. Hamilton, Astron. Royal of Ireland, &c. Rev. Professor Lloyd, F.R.S.
The MARQUIS OF LANSDOWNE, D.C.L., F.R.S. BRISTOL, August 22, 1836.	The Marquis of Northampton, F.R.S. Rev. W. D. Conybeare, F.R.S., F.G.S. J. C. Prichard, Esq., M.D., F.R.S.	Professor Daubeny, M.D., F.R.S., &c. V. F. Hovenden, Esq.
The EARL OF BURLINGTON, F.R.S., F.G.S., Chancellor of the University of London LIVERPOOL, September 11, 1837.	The Bishop of Norwich, P.L.S., F.G.S. John Dalton, Esq., D.C.L., F.R.S. Sir Philip de Grey Egerton, Bart., F.R.S., F.G.S. Rev. W. Whewell, F.R.S.	Professor Traill, M.D. Wm. Wallace Currie, Esq. Joseph N. Walker, Esq., Pres. Royal Institution Liverpool.
The DUKE OF NORTHUMBERLAND, F.R.S., F.G.S., &c. NEWCASTLE-ON-TYNE, August 20, 1838.	The Bishop of Durham, F.R.S., F.S.A. The Rev. W. Vernon Harcourt, F.R.S., &c. Prideaux John Selby, Esq., F.R.S.E.	John Adamson, Esq., F.L.S., &c. Wm. Hutton, Esq., F.G.S. Professor Johnston, M.A., F.R.S.
The REV. W. VERNON HARCOURT, M.A., F.R.S., &c. BIRMINGHAM, August 26, 1839.	The Marquis of Northampton. The Earl of Dartmouth. The Rev. T. R. Robinson, D.D. John Corrie, Esq., F.R.S. The Very Rev. Principal Macfarlane	George Barker, Esq., F.R.S. Peyton Blakiston, Esq., M.D. Joseph Hodgson, Esq., F.R.S. Follett Osler, Esq.

The MARQUIS OF BREADALBANE, F.R.S. GLASGOW, September 17, 1840.	Major-General Lord Greenock, F.R.S.E. Sir David Brewster, F.R.S. Sir T. M. Brisbane, Bart., F.R.S. The Earl of Mount-Edgcumbe	Andrew Liddell, Esq. Rev. J. P. Nicol, LL.D. John Strang, Esq.
The REV. PROFESSOR WHEWELL, F.R.S., &c. PLYMOUTH, July 29, 1841.	The Earl of Morley. Lord Eliot, M.P. Sir C. Lemon, Bart. Sir T. D. Acland, Bart.	W. Snow Harris, Esq., F.R.S. Col. Hamilton Smith, F.L.S. Robert Were Fox, Esq. Richard Taylor, jun., Esq.
The LORD FRANCIS EGERTON, F.G.S. MANCHESTER, June 23, 1842.	John Dalton, Esq., D.C.L., F.R.S. Hon. and Rev. W. Herbert, F.L.S., &c. Rev. A. Sedgwick, M.A., F.R.S. W. C. Henry, Esq., M.D., F.R.S. Sir Benjamin Heywood, Bart.	Peter Clare, Esq., F.R.A.S. W. Fleming, Esq., M.D. James Heywood, Esq., F.R.S.
The EARL OF ROSSE, F.R.S. CORK, August 17, 1843.	The Earl of Listowel. Viscount Adare Sir W. R. Hamilton, Pres. R.I.A. Rev. T. R. Robinson, D.D.	Professor John Stevelly, M.A. Rev. Jos. Carson, F.T.C. Dublin. William Keleher, Esq. Wm. Clear, Esq.
The REV. G. PEACOCK, D.D. (Dean of Ely), F.R.S. YORK, September 26, 1844.	Earl Fitzwilliam, F.R.S. Viscount Morpeth, F.G.S. The Hon. John Stuart Wortley, M.P. Sir David Brewster, K.H., F.R.S. Michael Faraday, Esq., D.C.L., F.R.S. Rev. W. V. Harcourt, F.R.S.	William Hatfeild, Esq., F.G.S. Thomas Meynell, Esq., F.L.S. Rev. W. Scoresby, LL.D., F.R.S. William West, Esq.
SIR JOHN F. W. HERSCHEL, Bart., F.R.S., &c. CAMBRIDGE, June 19, 1845.	The Earl of Hardwicke. The Bishop of Norwich Rev. J. Graham, D.D. Rev. G. Ainslie, D.D. G. B. Airy, Esq., M.A., D.C.L., F.R.S. The Rev. Professor Sedgwick, M.A., F.R.S.	William Hopkins, Esq., M.A., F.R.S. Professor Ansted, M.A., F.R.S.
SIR RODERICK IMPEY MURCHISON, G.C.St.S., F.R.S. SOUTHAMPTON, September 10, 1846.	The Marquis of Winchester. The Earl of Yarborough, D.C.L. Lord Ashburton, D.C.L. Viscount Palmerston, M.P. Right Hon. Charles Shaw Lefevre, M.P. Sir George T. Staunton, Bart., M.P., D.C.L., F.R.S. The Lord Bishop of Oxford, F.R.S. Professor Owen, M.D., F.R.S. The Rev. Professor Powell, F.R.S.	Henry Clark, Esq., M.D. T. H. C. Moody, Esq.
SIR ROBERT HARRY INGLIS, Bart., D.C.L., F.R.S., M.P. for the University of Oxford OXFORD, June 23, 1847.	The Earl of Rosse, F.R.S. The Lord Bishop of Oxford, F.R.S. The Vice-Chancellor of the University Thomas G. Bucknall Estcourt, Esq., D.C.L., M.P. for the University of Oxford. The Very Rev. the Dean of Westminster, D.D., F.R.S. Professor Daubeny, M.D., F.R.S. The Rev. Prof. Powell, M.A., F.R.S.	Rev. Robert Walker, M.A., F.R.S. H. Wentworth Acland, Esq., B.M.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The MARQUIS OF NORTHAMPTON, President of the Royal Society, &c. SWANSEA, August 9, 1848.	The Marquis of Bute, K.T. Viscount Adare, F.R.S. Sir H. T. De la Beche, F.R.S., Pres. G.S. The Very Rev. the Dean of Llandaff, F.R.S. Lewis W. Dillwyn, Esq., F.R.S. W. R. Grove, Esq., F.R.S. J. H. Vivian, Esq., M.P., F.R.S. The Lord Bishop of St. David's	Matthew Moggridge, Esq. D. Nicol, Esq., M.D.
The REV. T. R. ROBINSON, D.D., M.R.I.A., F.R.A.S. BIRMINGHAM, September 12, 1849.	The Earl of Harrowby. The Lord Wrottesley, F.R.S. The Right Hon. Sir Robert Peel, Bart., M.P., D.C.L., F.R.S. Charles Darwin, Esq., M.A., F.R.S., Sec. G.S. Professor Faraday, D.C.L., F.R.S. Sir David Brewster, K.H., LL.D., F.R.S. Rev. Prof. Willis, M.A., F.R.S.	Captain Tindal, R.N. William Wills, Esq. Bell Fletcher, Esq., M.D. James Chance, Esq.
SIR DAVID BREWSTER, K.H., LL.D., F.R.S. L. & E., Principal of the United College of St. Salvator and St. Leonard, St. Andrews EDINBURGH, July 21, 1850.	The Right Hon. the Lord Provost of Edinburgh The Earl of Cathcart, K.C.B., F.R.S.E. The Earl of Rosebery, K.T., D.C.L., F.R.S. The Right Hon. David Boyle (Lord Justice-General), F.R.S.E. General Sir Thomas M. Brisbane, Bart., D.C.L., F.R.S., Pres. R.S.E. The Very Rev. John Lee, D.D., V.P.R.S.E., Principal of the University of Edinburgh. Professor W. P. Alison, M.D., V.P.R.S.E. Professor J. D. Forbes, F.R.S., Sec. R.S.E.	Rev. Professor Kelland, M.A., F.R.S. L. & E. Professor Balfour, M.D., F.R.S.E., F.L.S. James Tod, Esq., F.R.S.E.
GEORGE BIDDELL AIRY, Esq., D.C.L., F.R.S., Astronomer Royal IPSWICH, July 2, 1851.	The Lord Rendlesham, M.P. The Lord Bishop of Norwich Rev. Professor Sedgwick, M.A., F.R.S. Rev. Professor Henslow, M.A., F.L.S. Sir John P. Boileau, Bart., F.R.S. Sir William F. F. Middleton, Bart. J. C. Cobbold, Esq., M.P. T. B. Western, Esq.	Charles May, Esq., F.R.A.S. Dillwyn Sims, Esq. George Arthur Biddell, Esq. George Ransome, Esq., F.L.S.
COLONEL EDWARD SABINE, Royal Artillery, Treas. & V.P. of the Royal Society BELFAST, September 1, 1852.	The Earl of Enniskillen, D.C.L., F.R.S. The Earl of Rosse, Pres. R.S., M.R.I.A. Sir Henry T. De la Beche, F.R.S. Rev. Edward Hincks, D.D., M.R.I.A. Rev. P. S. Henry, D.D., Pres. Queen's College, Belfast Rev. T. R. Robinson, D.D., Pres. R.I.A., F.R.A.S. Professor G. G. Stokes, F.R.S. Professor Stevelly, LL.D.	W. J. C. Allen, Esq. William M'Gee, Esq., M.D. Professor W. P. Wilson.
WILLIAM HOPKINS, Esq., M.A., V.P.R.S., F.G.S., Pres. Camb. Phil. Society HULL, September 7, 1853.	The Earl of Carlisle, F.R.S. Lord Londesborough, F.R.S. Professor Faraday, D.C.L., F.R.S. Rev. Prof. Sedgwick, M.A., F.R.S. Charles Frost, Esq., F.S.A., Pres. of the Hull Lit. and Phil. Society William Spence, Esq., F.R.S. Lieut.-Col. Sykes, F.R.S. Professor Wheatstone, F.R.S.	Henry Cooper, Esq., M.D., V.P. Hull Lit. & Phil. Society. Bethel Jacobs, Esq., Pres. Hull Mechanics' Inst.
The EARL OF HARROWBY, F.R.S. LIVERPOOL, September 20, 1854.	The Lord Wrottesley, M.A., F.R.S., F.R.A.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Professor Owen, M.D., LL.D., F.R.S., F.L.S., F.G.S. Rev. Professor Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., Master of Trinity College, Cambridge William Lassell, Esq., F.R.S. L. & E., F.R.A.S. Joseph Brooks Yates, Esq., F.S.A., F.R.G.S.	Joseph Dickinson, Esq., M.D., F.R.S. Thomas Inman, Esq., M.D.

The DUKE OF ARGYLL, F.R.S., F.G.S. GLASGOW, September 12, 1855.	The Very Rev. Principal Macfarlane, D.D. Sir William Jardine, Bart., F.R.S.E. Sir Charles Lyell, M.A., LL.D., F.R.S. James Smith, Esq., F.R.S. L. & E. Walter Crum, Esq., F.R.S. Thomas Graham, Esq., M.A., F.R.S., Master of the Royal Mint Professor William Thomson, M.A., F.R.S.	John Strang, Esq., LL.D. Professor Thomas Anderson, M.D. William Gourlie, Esq.
CHARLES G. B. DAUBENY, Esq., M.D., LL.D., F.R.S., Professor of Botany in the University of Oxford. CHELTENHAM, August 6, 1856.	The Earl of Ducie, F.R.S., F.G.S. The Lord Bishop of Gloucester and Bristol Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. Thomas Barwick Lloyd Baker, Esq. The Rev. Francis Close, M.A.	Capt. Robinson, R.A. Richard Beamish, Esq., F.R.S. John West Hugell, Esq.
The REV. HUMPHREY LLOYD, D.D., D.C.L., F.R.S., F.R.S.E., V.P.R.I.A. DUBLIN, August 26, 1857.	The Right Hon. the Lord Mayor of Dublin The Provost of Trinity College, Dublin The Marquis of Kildare. Lord Talbot de Malahide The Lord Chancellor of Ireland The Lord Chief Baron, Dublin Sir William R. Hamilton, LL.D., F.R.A.S., Astronomer Royal of Ireland Lieut.-Colonel Larcom, R.E., LL.D., F.R.S. Richard Griffith, Esq., LL.D., M.R.I.A., F.R.S.E., F.G.S.	Lundy E. Foote, Esq. Rev. Professor Jellett, F.T.C.D. W. Neilson Hancock, Esq. LL.D.
RICHARD OWEN, Esq., M.D., D.C.L., V.P.R.S., F.L.S., F.G.S., Superintendent of the Natural History Departments of the British Museum. LEEDS, September 22, 1858.	The Lord Monteagle, F.R.S. The Lord Viscount Goderich, M.P., F.R.G.S. The Right Hon. M. T. Baines, M.A., M.P. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. The Rev. W. Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., F.R.A.S., Master of Trinity College, Cambridge James Garth Marshall, Esq., M.A., F.G.S. R. Monckton Milnes, Esq., D.C.L., M.P., F.R.G.S.	Rev. Thomas Hincks, B.A. W. Sykes Ward, Esq., F.C.S. Thomas Wilson, Esq., M.A.
HIS ROYAL HIGHNESS THE PRINCE CONSORT. ABERDEEN, September 14, 1859.	The Duke of Richmond, K.G., F.R.S. The Earl of Aberdeen, LL.D., K.G., K.T., F.R.S. The Lord Provost of the City of Aberdeen Sir John F. W. Herschel, Bart., M.A., D.C.L., F.R.S. Sir David Brewster, K.H., D.C.L., F.R.S. Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. The Rev. W. V. Harcourt, M.A., F.R.S. The Rev. T. R. Robinson, D.D., F.R.S. A. Thomson, Esq., LL.D., F.R.S., Convener of the County of Aberdeen	Professor J. Nicol, F.R.S.E., F.G.S. Professor Fuller, M.A. John F. White, Esq.
The LORD WROTTESLEY, M.A., V.P.R.S., F.R.A.S. OXFORD, June 27, 1860.	The Earl of Derby, K.G., P.C., D.C.L., Chancellor of the Univ. of Oxford The Rev. F. Jeune, D.C.L., Vice-Chancellor of the University of Oxford The Duke of Marlborough, D.C.L., F.G.S., Lord Lieutenant of Oxfordshire The Earl of Rosse, K.P., M.A., F.R.S., F.R.A.S. The Lord Bishop of Oxford, D.D., F.R.S. The Very Rev. H. G. Liddell, D.D., Dean of Christ Church, Oxford Professor Daubeny, M.D., LL.D., F.R.S., F.L.S., F.G.S. Professor Acland, M.D., F.R.S. Professor Donkin, M.A., F.R.S., F.R.A.S.	George Rolleston, Esq., M.D., F.L.S. H. J. S. Smith, Esq., M.A., F.C.S. George Griffith, Esq., M.A., F.C.S.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
WILLIAM FAIRBAIRN, Esq., LL.D., C.E., F.R.S. MANCHESTER, September 4, 1861.	The Earl of Ellesmere, F.R.G.S. The Lord Stanley, M.P., D.C.L., F.R.G.S. The Lord Bishop of Manchester, D.D., F.R.S., F.G.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Sir Benjamin Heywood, Bart., F.R.S. Thomas Bazley, Esq., M.P. James Aspinall Turner, Esq., M.P. James Prescott Joule, Esq., LL.D., F.R.S., Pres. Lit. & Phil. Soc. Manchester Professor E. Hodgkinson, F.R.S., M.R.I.A., M.Inst.C.E. Joseph Whitworth, Esq., F.R.S., M.Inst.C.E.	R. D. Darbishire, Esq., B.A., F.G.S. Alfred Neild, Esq. Arthur Ransome, Esq., M.A. Professor H. E. Roscoe, B.A.
The REV. R. WILLIS, M.A., F.R.S., Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge CAMBRIDGE, October 1, 1862.	The Rev. the Vice-Chancellor of the University of Cambridge The Very Rev. Harvey Goodwin, D.D., Dean of Ely The Rev. W. Whewell, D.D., F.R.S., Master of Trinity College, Cambridge The Rev. Professor Sedgwick, M.A., D.C.L., F.R.S. The Rev. J. Challis, M.A., F.R.S. G. B. Airy, Esq., M.A., D.C.L., F.R.S., Astronomer Royal Professor G. G. Stokes, M.A., D.C.L., Sec. R.S. Professor J. C. Adams, M.A., D.C.L., F.R.S., Pres. C.P.S.	Professor C. C. Babington, M.A., F.R.S., F.L.S. Professor G. D. Liveing, M.A. The Rev. N. M. Ferrers, M.A.
SIR W. ARMSTRONG, C.B., LL.D., F.R.S. NEWCASTLE-ON-TYNE, August 26, 1863.	Sir Walter C. Trevelyan, Bart., M.A. Sir Charles Lyell, LL.D., D.C.L., F.R.S., F.G.S. Hugh Taylor, Esq., Chairman of the Coal Trade Isaac Lowthian Bell, Esq., Mayor of Newcastle Nicholas Wood, Esq., President of the Northern Institute of Mining Engineers Rev. Temple Chevallier, B.D., F.R.A.S. William Fairbairn, Esq., LL.D., F.R.S.	A. Noble, Esq. Augustus H. Hunt, Esq. R. C. Clapham, Esq.
SIR CHARLES LYELL, Bart., M.A., D.C.L., F.R.S. BATH, September 14, 1864.	The Right Hon. the Earl of Cork and Orrery, Lord-Lieutenant of Somersetshire The Most Noble the Marquis of Bath The Right Hon. Earl Nelson The Right Hon. Lord Portman The Very Rev. the Dean of Hereford The Venerable the Archdeacon of Bath W. Tite, Esq., M.P., F.R.S., F.G.S., F.S.A. A. E. Way, Esq., M.P. Francis H. Dickinson, Esq. W. Sanders, Esq., F.R.S., F.G.S.	C. Moore, Esq., F.G.S. C. E. Davis, Esq. The Rev. H. H. Winwood, M.A.
JOHN PHILLIPS, Esq., M.A., LL.D., F.R.S., F.G.S., Professor of Geology in the University of Oxford BIRMINGHAM, September 6, 1865.	The Right Hon. the Earl of Lichfield, Lord-Lieutenant of Staffordshire The Right Hon. the Earl of Dudley The Right Hon. Lord Leigh, Lord-Lieutenant of Warwickshire The Right Hon. Lord Lyttelton, Lord-Lieutenant of Worcestershire The Right Hon. Lord Wrottesley, M.A., D.C.L., F.R.S., F.R.A.S. The Right Rev. the Lord Bishop of Worcester The Right Hon. C. B. Adderley, M.P. William Scholefield, Esq., M.P. F. Osler, Esq., F.R.S. J. T. Chance, Esq. The Rev. Charles Evans, M.A.	William Mathews, jun., Esq., M.A., F.G.S. John Henry Chamberlain, Esq. The Rev. G. D. Boyle, M.A.

WILLIAM R. GROVE, Esq., Q.C., M.A., F.R.S. NOTTINGHAM, August 22, 1866.	His Grace the Duke of Devonshire, Lord-Lieutenant of Derbyshire His Grace the Duke of Rutland, Lord-Lieutenant of Leicestershire The Right Hon. Lord Belper, Lord-Lieutenant of Nottinghamshire The Right Hon. J. E. Denison, M.P. J. C. Webb, Esq., High-Sheriff of Nottinghamshire Thomas Graham, Esq., F.R.S., Master of the Mint Joseph Hooker, Esq., M.D., F.R.S., F.L.S. John Russell Hind, Esq., F.R.S., F.R.A.S. T. Close, Esq.	Dr. Robertson. Edward J. Lowe, Esq., F.R.A.S., F.L.S. The Rev. J. F. M'Callan, M.A.
HIS GRACE THE DUKE OF BUCCLEUCH, K.G., D.C.L., F.R.S. DUNDEE, September 4, 1867.	The Right Hon. the Earl of Airlie, K.T. The Right Hon. the Lord Kinnaird, K.T. Sir John Ogilvy, Bart., M.P. Sir Roderick I. Murchison, Bart., K.C.B., LL.D., F.R.S., F.G.S., &c. Sir David Baxter, Bart. Sir David Brewster, D.C.L., F.R.S., Principal of the University of Edinburgh James D. Forbes, Esq., LL.D., F.R.S., Principal of the United College of St. Salvator and St. Leonard, University of St. Andrews	J. Henderson, jun., Esq. John Austin Lake Gloag, Esq. Patrick Anderson, Esq.
JOSEPH DALTON HOOKER, Esq., M.D., D.C.L., F.R.S., F.L.S. NORWICH, August 19, 1868.	The Right Hon. the Earl of Leicester, Lord-Lieutenant of Norfolk Sir John Peter Boileau, Bart., F.R.S. The Rev. Adam Sedgwick, M.A., LL.D., F.R.S., F.G.S., &c., Woodwardian Professor of Geology in the University of Cambridge Sir John Lubbock, Bart., F.R.S., F.L.S., F.G.S. John Couch Adams, Esq., M.A., D.C.L., F.R.S., F.R.A.S., Lowndean Professor of Astronomy and Geometry in the University of Cambridge Thomas Brightwell, Esq.	Dr. Donald Dalrymple. Rev. Joseph Crompton, M.A. Rev. Canon Hinds Howell.
PROFESSOR GEORGE G. STOKES, D.C.L., F.R.S. EXETER, August 18, 1869.	The Right Hon. the Earl of Devon The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., &c. Sir John Bowring, LL.D., F.R.S. William B. Carpenter, Esq., M.D., F.R.S., F.L.S. Robert Were Fox, Esq., F.R.S. W. H. Fox Talbot, Esq., M.A., LL.D., F.R.S., F.L.S.	Henry S. Ellis, Esq., F.R.A.S. John C. Bowring, Esq. The Rev. R. Kirwan.
PROFESSOR T. H. HUXLEY, LL.D., F.R.S., F.G.S. LIVERPOOL, September 14, 1870.	The Right Hon. the Earl of Derby, LL.D., F.R.S. Sir Philip de Malpas Grey Egerton, Bart., M.P. The Right Hon. W. E. Gladstone, D.C.L., M.P. S. R. Graves, Esq., M.P. Sir Joseph Whitworth, Bart., LL.D., D.C.L., F.R.S. James P. Joule, Esq., LL.D., D.C.L., F.R.S. Joseph Mayer, Esq., F.S.A., F.R.G.S.	Rev. W. Banister. Reginald Harrison, Esq. Rev. Henry H. Higgins, M.A. Rev. Dr. A. Hume, F.S.A.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES
PROFESSOR SIR WILLIAM THOMSON, M.A., LL.D., F.R.S., F.R.S.E. EDINBURGH, August 2, 1871.	His Grace the Duke of Buccleuch, K.G., D.C.L., F.R.S. The Right Hon. the Lord Provost of Edinburgh The Right Hon. John Inglis, LL.D., Lord Justice-General of Scotland Sir Alexander Grant, Bart., M.A., Principal of the University of Edinburgh Sir Roderick I. Murchison, Bart., K.C.B., G.C.St.S., D.C.L., F.R.S. Sir Charles Lyell, Bart., D.C.L., F.R.S., F.G.S. Dr. Lyon Playfair, C.B., M.P., F.R.S. Professor Christison, M.D., D.C.L., Pres. R.S.E. Professor Balfour, F.R.S. L. & E.	Professor A. Crum Brown, M.D., F.R.S.E. J. D. Marwick, Esq., F.R.S.E.
W. B. CARPENTER, Esq., M.D., LL.D., F.R.S., F.L.S. BRIGHTON, August 14, 1872.	The Right Hon. the Earl of Chichester, Lord-Lieutenant of the County of Sussex. His Grace the Duke of Norfolk His Grace the Duke of Richmond, K.G., P.C., D.C.L. His Grace the Duke of Devonshire, K.G., D.C.L., F.G.S. Sir John Lubbock, Bart., M.P., F.R.S., F.L.S., F.G.S. Dr. Sharpey, LL.D., Sec. R.S., F.L.S. Joseph Prestwich, Esq., F.R.S., Pres. G.S.	Charles Carpenter, Esq. The Rev. Dr. Griffith. Henry Willett, Esq.
PROFESSOR ALEXANDER W. WILLIAMSON, Ph.D., F.R.S., F.C.S. BRADFORD, September 17, 1873.	The Right Hon. the Earl of Rosse, F.R.S., F.R.A.S. The Right Hon. Lord Houghton, D.C.L., F.R.S. The Right Hon. W. E. Forster, M.P. The Mayor of Bradford. Sir John Hawkshaw, F.R.S., F.G.S. J. P. Gassiot, Esq., D.C.L., F.R.S. Professor Phillips, D.C.L., F.R.S.	The Rev. J. R. Campbel, D.D. Richard Goddard, Esq. Peile Thompson, Esq.
PROFESSOR J. TYNDALL, D.C.L., LL.D., F.R.S. BELFAST, August 19, 1874.	The Right Hon. the Earl of Enniskillen, D.C.L., F.R.S. The Right Hon. the Earl of Rosse, F.R.S. Sir Richard Wallace, Bart., M.P. The Rev. Dr. Henry. Dr. Andrews, F.R.S. The Rev. Dr. Robinson, F.R.S. Professor Stokes, D.C.L., F.R.S.	W. Quartus Ewart, Esq. Professor G. Fuller, C.E. T. Sinclair, Esq.
SIR JOHN HAWKSHAW, M.Inst.C.E., F.R.S., F.G.S. BRISTOL, August 25, 1875.	The Right Hon. the Earl of Ducie, F.R.S., F.G.S. The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., F.R.S. The Mayor of Bristol Major-General Sir Henry C. Rawlinson, K.C.B., LL.D., F.R.S., F.R.G.S. Dr. W. B. Carpenter, LL.D., F.R.S., F.L.S., F.G.S. W. Sanders, Esq., F.R.S., F.G.S.	W. Lant Carpenter, Esq., B.A., B.Sc., F.C.S. John H. Clarke, Esq.
PROFESSOR THOMAS ANDREWS, M.D., LL.D., F.R.S., Hon. F.R.S.E. GLASGOW, September 6, 1876.	His Grace the Duke of Argyll, K.T., LL.D., F.R.S., F.R.S.E., F.G.S. The Hon. the Lord Provost of Glasgow Sir William Stirling Maxwell, Bart., M.A., M.P. Professor Sir William Thomson, M.A., LL.D., D.C.L., F.R.S., F.R.S.E. Professor Allen Thomson, M.D., LL.D., F.R.S., F.R.S.E. Professor A. C. Ramsay, LL.D., F.R.S., F.G.S. James Young, Esq., F.R.S., F.C.S.	Dr. W. G. Blackie, F.R.G.S. James Grahame, Esq. J. D. Marwick, Esq.

PROFESSOR ALLEN THOMSON, M.D., LL.D., F.R.S F.R.S.E. PLYMOUTH, August 15, 1877.	. Hon. the Earl of Mount-Edgcumbe t Hon. Lord Blachford, K.C.M.G. Spottiswoode, Esq., M.A., LL.D., F.R.S., F.R.A.S., F.R.G.S. Froude, Esq., M.A., C.E., F.R.S. pence Bate, Esq., F.R.S.. F.L.S.	William Adams, Esq. William Square, Esq. Hamilton Whiteford Esq.
WILLIAM SPOTTISWOODE, Esq., M.A., D.C.L., LL.D F.R.S., F.R.A.S., F.R.G.S. DUBLIN, August 14, 1878.	t Hon. the Lord Mayor of Dublin ost of Trinity College, Dublin e the Duke of Abercorn, K.G. t Hon. the Earl of Enniskillen, D.C.L., F.R.S., F.G.S. it Hon. the Earl of Rosse, B.A., D.C.L., F.R.S., F.R.A.S., [.A The Right Hon. Lord O'Hagan, M.R.I.A. G. Stokes, M.A., D.C.L., LL.D., Sec. R.S.	Professor R. S. Ball, M.A., F.R.S. James Goff, Esq. John Norwood, Esq., LL.D. Professor G. Sigerson, M.D.
PROFESSOR G. J. ALLMAN, M.D., LL.D., F.R.S., F.R.S.E. M.R.I.A., Pres. L.S. SHEFFIELD, August 20, 1879.	e tl Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.R.G.S. t E . the Earl Fitzwilliam, K.G., F.R.G.S. t H . the Earl of Wharncliffe, F.R.G.S. tta Esq. (Master Cutler) rofessor T. H. Huxley, Ph.D., LL.D., Sec. R.S., F.L.S., F.G.S. rofessor W. Odling, M.B., F.R.S., F.C.S.	H. Clifton Sorby, Esq., LL.D., F.R.S., F.G.S. J. F. Moss, Esq.
ANDREW CROMBIE RAMSAY, Esq., LL.D., F.R.S. V.P.G.S., Director-General of the Geological Survey o the United Kingdom, and of the Museum of Practica Geology. SWANSEA, August 25, 1880.	he Right Hon. the Earl of Jersey he Mayor of Swansea he Hon. Sir W. R. Grove, M.A., D.C.L., F.R.S. . Hussey Vivian, Esq., M.P., F.G.S. . Ll. Dillwyn, Esq., M.P., F.L.S., F.G.S. . Gwyn Jeffreys, Esq., LL.D., F.R.S., F.L.S., Treas. G.S., F.R.G.S.	W. Morgan Esq., Ph.D., F.C.S. James Strick, Esq.
SIR JOHN LUBBOCK, Bart., M.P., D.C.L., LL.D., F.R.S. Pres. L.S., F.G.S. YORK, August 31, 1881.	is Grace the Archbishop of York, D.D., F.R.S. he Right Hon. the Lord Mayor of York he Right Hon. Lord Houghton, D.C.L., F.R.S., F.R.G.S. he Venerable Archdeacon Creyke, M.A. he Hon. Sir W. R. Grove, M.A., D.C.L., F.R.S. rofessor G. G. Stokes, M.A., D.C.L., LL.D., Sec. R.S. r John Hawkshaw, M.Inst.C.E F.R.S., F.G.S., F.R.G.S. llen Thomson, Esq., M.D., LL.D., F.R.S. L. & E. rofessor Allman, M.D., LL.D., F.R.S. L. & E., F.L.S.	Rev. Thomas Adams, M.A. Tempest Anderson, Esq., M.D., B.S
C. W. SIEMENS, Esq., D.C.L., LL.D., F.R.S., F.C.S., M.Inst.C.E. SOUTHAMPTON, August 23, 1882.	he Right Hon. the Lord Mount-Temple aptain Sir F. J. Evans, K.C.B., F.R.S., F.R.A.S., F.R.G.S., Hydrographer to the Admiralty . A. Abel, Esq., C.B., F.R.S., V.P.C.S., Director of the Chemical Establishment of the War Department rofessor De Chaumont, M.D., F.R.S. ajor-General A. C. Cooke, R.E., C.B., F.R.G.S., Director-General of the Ordnance Survey. Wyndham S. Portal, Esq. rofessor Prestwich, M.A., F.R.S., F.G.S., F.C.S. hilip Lutley Sclater, Esq., M.A., Ph.D., F.R.S., F.L.S., F.G.S.	C. W. A. Jellicoe, Esq. John E. Le Feuvre, Esq. Morris Miles, Esq.

	VICE-PRESIDENTS.	LOCAL SECRETARIES
ARTHUR CAYLEY, Esq., M.A., D.C.L., LL.D., F.R.S., V.P.R.A.S., Sadlerian Professor of Pure Mathematics in the University of Cambridge .... SOUTHPORT, September 19, 1883.	The Right Hon. the Earl of Derby, M.A., LL.D., F.R.S., F.R.G.S. ...... The Right Hon. the Earl of Crawford and Balcarres, LL.D., F.R.S., F.R.A.S. The Right Hon. the Earl of Lathom.... Principal J. W. Dawson, C.M.G., M.A., LL.D., F.R.S., F.G.S. .... J. G. Greenwood, Esq., LL.D., Vice-Chancellor of the Victoria University Professor H. E. Roscoe, Ph.D., LL.D., F.R.S., F.C.S.	J. H. Ellis, Esq. Dr. Vernon. T. W. Willis, Esq.
The RIGHT HON. LORD RAYLEIGH, M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S., Professor of Experimental Physics in the University of Cambridge. ...... MONTREAL, August 27, 1884.	His Excellency the Governor-General of Canada, G.C.M.G., LL.D..... The Right Hon. Sir John Alexander Macdonald, K.C.B., D.C.L., LL.D. The Right Hon. Sir Lyon Playfair, K.C.B., M.P., LL.D., F.R.S. L. & E. The Hon. Sir Alexander Tilloch Galt, G.C.M.G. .... The Hon. Sir Charles Tupper, K.C.M.G. .... Chief Justice Sir A. A. Dorion, C.M.G. .... Principal Sir William Dawson, C.M.G., M.A., LL.D., F.R.S., F.G.S.... The Hon. Dr. Chauveau. .... Professor Edward Frankland, M.D., D.C.L., Ph.D., LL.D., F.R.S., F.C.S. W. H. Hingston, Esq., M.D., D.C.L., L.R.C.S.E. .... Thomas Sterry Hunt, Esq., M.A., D.Sc., LL.D., F.R.S.	S. E. Dawson, Esq. R. A. Ramsay, Esq. S. Rivard, Esq. S. C. Stevenson, Esq. Thos. White, Esq., M.P.
The RIGHT HON. SIR LYON PLAYFAIR, K.C.B., M.P., Ph.D., LL.D., F.R.S., F.R.S.E., F.C.S. .... ABERDEEN, September 9, 1885.	His Grace the Duke of Richmond and Gordon, K.G., D.C.L., Chancellor of the University of Aberdeen .... The Right Hon. the Earl of Aberdeen, LL.D., Lord-Lieutenant of Aberdeenshire .... The Right Hon. the Earl of Crawford and Balcarres, M.A., LL.D., F.R.S., F.R.A.S. .... James Matthews, Esq., Lord Provost of the City of Aberdeen .... Professor Sir William Thomson, M.A., LL.D., F.R.S., F.R.S.E., F.R.A.S. Alexander Bain, Esq., M.A., LL.D., Rector of the University of Aberdeen .... The Very Rev. Principal Pirie, D.D., Vice-Chancellor of the University of Aberdeen .... Professor W. H. Flower, LL.D., F.R.S., F.L.S., Pres. Z.S., F.G.S., Director of the Natural History Museum, London .... Professor John Struthers, M.D., LL.D.	J. W. Crombie, Esq., M.A. Angus Fraser, Esq., M.A., M.D., F.C.S. Professor G. Pirie, M.A.
SIR J. WILLIAM DAWSON, C.M.G., M.A., LL.D., F.R.S., F.G.S., Principal and Vice-Chancellor of McGill University, Montreal, Canada .... BIRMINGHAM, September 1, 1886.	The Right Hon. the Earl of Bradford, Lord-Lieutenant of Shropshire. The Right Hon. Lord Leigh, D.C.L., Lord-Lieutenant of Warwickshire. The Right Hon. Lord Norton, K.C.M.G. .... The Right Hon. Lord Wrottesley, Lord-Lieutenant of Staffordshire .. The Right Rev. the Lord Bishop of Worcester, D.D. .... Thomas Martineau, Esq., Mayor of Birmingham...................... Professor G. G. Stokes, M.A., D.C.L., LL.D., Pres. R.S. .... Professor W. A. Tilden, D.Sc., F.R.S., F.C.S. .... Rev. A. R. Vardy, M.A. .... Rev. H. W. Watson, D.Sc., F.R.S.	J. Barham Carslake, Esq. Rev. H. W. Crosskey, LL.D., F.G.S. Charles J. Hart, Esq.

Presidents	Vice-Presidents	Local Secretaries
SIR H. E. ROSCOE, M.P., D.C.L., LL.D., Ph.D., F.R.S., V.P.C.S. MANCHESTER, August 31, 1887.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.G.S., F.R.G.S. The Right Hon. the Earl of Derby, K.G., M.A., LL.D., F.R.S., F.R.G.S. The Right Rev. the Lord Bishop of Manchester, D.D. The Right Rev. the Bishop of Salford The Right Worshipful the Mayor of Manchester The Right Worshipful the Mayor of Salford The Vice-Chancellor of the Victoria University The Principal of the Owens College Sir William Roberts, B.A., M.D., F.R.S. Thomas Ashton, Esq., J.P., D.L. Oliver Heywood, Esq., J.P., D.L. James Prescott Joule, Esq., D.C.L., LL.D., F.R.S., F.R.S.E., F.C.S.	F. J. Faraday, Esq., F.L.S., F.S.S. Charles Hopkinson, Esq., B.Sc. Professor A. Milnes Marshall, M.A., M.D., D.Sc., F.R.S. Professor A. H. Young, M.B., F.R.C.S.
SIR FREDERICK J. BRAMWELL, D.C.L., F.R.S., M.Inst.C.E. BATH, September 5, 1888.	The Right Hon. the Earl of Cork and Orrery, Lord-Lieutenant of Somerset The Most Hon. the Marquess of Bath The Right Hon. and Right Rev. the Lord Bishop of Bath and Wells, D.D. The Right Rev. the Bishop of Clifton, D.D. The Right Worshipful the Mayor of Bath The Right Worshipful the Mayor of Bristol Sir F. A. Abel, C.B., D.C.L., F.R.S., V.P.C.S. The Venerable the Archdeacon of Bath, M.A. The Rev. Leonard Blomefield, M.A., F.L.S., F.G.S. Professor Michael Foster, M.A., M.D., LL.D., Sec. R.S., F.L.S., F.C.S. W. S. Gore-Langton, Esq., J.P., D.L. H. D. Skrine, Esq., J.P., D.L. Colonel R. P. Laurie, C.B., M.P. E. R. Wodehouse, Esq., M.P. Jerom Murch, Esq., J.P., D.L.	W. Pumphrey, Esq. J. L. Stothert, Esq., M.Inst.C.E. B. H. Watts, Esq.
PROFESSOR WILLIAM HENRY FLOWER, C.B., LL.D., F.R.S., F.R.C.S., Pres. Z.S., F.L.S., F.G.S., Director of the Natural History Departments of the British Museum. NEWCASTLE-UPON-TYNE, September 11, 1889.	His Grace the Duke of Northumberland, K.G., D.C.L., LL.D., Lord-Lieutenant of Northumberland The Right Hon. the Earl of Durham, Lord-Lieutenant of Durham The Right Hon. the Earl of Ravensworth The Right Rev. the Lord Bishop of Newcastle, D.D. The Right Hon. Lord Armstrong, C.B., D.C.L., LL.D., F.R.S. The Right Hon. John Morley, M.P., LL.D. The Very Rev. the Warden of the University of Durham, D.D. The Right Worshipful the Mayor of Newcastle The Worshipful the Mayor of Gateshead Sir I. Lowthian Bell, Bart., D.C.L., F.R.S., F.C.S., M.Inst.C.E. Sir Charles Mark Palmer, Bart., M.P.	Professor P. Phillips Bedson, D.Sc., F Professor J. Herman Merivale, M.A.
SIR FREDERICK AUGUSTUS ABEL, C.B., D.C.L., D.Sc., F.R.S., P.P.C.S., Hon.M.Inst.C.E. LEEDS, September 3, 1890.	His Grace the Duke of Devonshire, K.G., M.A., LLD., F.R.S., F.G.S. The Most Hon. the Marquess of Ripon, K.G., G.C.S.I., C.I.E., F.R.S. The Right Hon. the Earl Fitzwilliam, K.G., F.R.G.S. The Right Rev. the Lord Bishop of Ripon, D.D. The Right Hon. Sir Lyon Playfair, K.C.B., Ph.D., LL.D., M.P., F.R.S. The Right Hon. W. L. Jackson, M.P. The Mayor of Leeds Sir James Kitson, Bart., M.Inst.C.E. Sir Andrew Fairbairn, M.A.	J. Rawlinson Ford, Esq. Sydney Lupton, Esq., M.A. Professor L. C. Miall, F.L.S., F.G.S. Professor A. Smithells, B.Sc.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
WILLIAM HUGGINS, Esq., D.C.L., LL.D., Ph.D., F.R.S., F.R.A.S., Hon. F.R.S.E. CARDIFF, August 19, 1891.	The Right Hon. Lord Windsor, Lord-Lieutenant of Glamorganshire The Most Hon. the Marquess of Bute, K.T. The Right Hon. Lord Rayleigh, M.A., D.C.L., LL.D., Sec.R.S., F.R.A.S. The Right Hon. Lord Tredegar The Right Hon. Lord Aberdare, G.C.B., F.R.S., F.R.G.S. Sir J. T. D. Llewelyn, Bart., F.Z.S. Sir Archibald Geikie, LL.D., D.Sc., For.Sec.R.S., F.R.S.E., Pres.G.S. Sir Robert Ball, LL.D., F.R.S., F.R.A.S., Royal Astronomer of Ireland	R. W. Atkinson, Esq., B.Sc., F.C.S., F.I.C. Professor H. W. Lloyd Tanner, M.A., F.R.A.S.
SIR ARCHIBALD GEIKIE, LL.D., D.Sc., For.Sec. R.S., F.R.S.E., F.G.S., Director-General of the Geological Survey of the United Kingdom. EDINBURGH, August 3, 1892.	The Right Hon. the Lord Provost of Edinburgh The Most Hon. the Marquess of Lothian, K.T. The Right Hon. the Earl of Rosebery, LL.D., F.R.S., F.R.S.E. The Right Hon. J. H. A. Macdonald C.B., LL.D., F.R.S., F.R.S.E. Principal Sir William Muir, K.C.S.I., D.C.L. Professor Sir Douglas Maclagan, M.D., Pres.R.S.E. Professor Sir William Turner, F.R.S., F.R.S.E. Professor P. G. Tait, M.A., F.R.S.E. Professor A. Crum Brown, M.D., F.R.S., F.R.S.E., Pres.C.S.	Professor G. F. Armstrong, M.A., M.Inst.C.E., F.R.S.E., F.G.S. F. Grant Ogilvie, Esq., M.A., B.Sc., F.R.S.E. John Harrison, Esq.
DR. J. S. BURDON SANDERSON, M.A., M.D., LL.D., D.C.L., F.R.S., F.R.S.E., Professor of Physiology in the University of Oxford. NOTTINGHAM, September 13, 1893.	His Grace the Duke of St. Albans, Lord-Lieut. of Nottinghamshire His Grace the Duke of Devonshire, K.G., Chancellor of the University of Cambridge His Grace the Duke of Portland. His Grace the Duke of Newcastle The Right Hon. Lord Belper. The Mayor of Nottingham The Right Hon. Sir W. R. Grove, F.R.S. Sir John Turney, J.P. Professor Michael Foster, M.A., Sec.R.S. W. H. Ransom, Esq., M.D., F.R.S.	Professor F. Clowes, D.Sc. Professor W. H. Heaton, M.A. Arthur Williams, Esq.
The MOST HON. THE MARQUIS OF SALISBURY, K.G., D.C.L., F.R.S., Chancellor of the University of Oxford. OXFORD, August 8, 1894.	The Right Hon. the Earl of Jersey, G.C.M.G., Lord-Lieutenant of the County of Oxford The Right Hon. Lord Wantage, K.C.B., V.C., Lord-Lieutenant of Berkshire The Right Hon. the Earl of Rosebery, K.G., D.C.L., F.R.S. The Right Rev. the Lord Bishop of Oxford, D.D. The Right Hon. Lord Rothschild, Lord-Lieutenant of Buckinghamshire The Right Hon. Lord Kelvin, D.C.L., Pres.R.S. The Rev. the Vice-Chancellor of the University of Oxford The Mayor of Oxford Sir W. R. Anson, D.C.L., Warden of All Souls College Sir Bernhard Samuelson, Bart., M.P., F.R.S. Sir Henry Dyke Acland, Bart., M.D., F.R.S., Regius Professor of Medicine The Rev. B. Price, D.D., F.R.S., Sedleian Professor of Natural Philosophy Dr. J. J. Sylvester, F.R.S., Savilian Professor of Geometry	Gilbert C. Bourne, Esq., M.A. G. C. Druce, Esq., M.A. D. H. Nagel, Esq., M.A.

CAPTAIN SIR DOUGLAS GALTON, K.C.B., D.C.L., LL.D., F.R.S., F.R.G.S., F.G.S. IPSWICH, September 11, 1895.	[illegible] County of Suffolk The Right Hon. Lord Walsingham, LL.D., F.R.S., High Steward of the University of Cambridge The Right Hon. Lord Rayleigh, Sec.R.S., Lord-Lieutenant of Essex The Right Hon. Lord Gwydyr, M.A., High Steward of Ipswich The Right Hon. Lord Henniker, F.S.A. The Right Hon. Lord Rendlesham J. H. Bartlet, Esq., Mayor of Ipswich Sir G. G. Stokes, Bart., D.C.L., F.R.S. Dr. E. Frankland, D.C.L., F.R.S. Professor G. H. Darwin, M.A., F.R.S. Felix T. Cobbold, Esq., M.A.	G. H. Hewetson, Esq. S. A. Notcutt, Esq., B.A., LL.M., B.Sc. E. P. Ridley, Esq.
SIR JOSEPH LISTER, BART., D.C.L., LL.D., President of the Royal Society LIVERPOOL, September 16, 1896.	The Right Hon. the Earl of Derby, G.C.B., Lord Mayor of Liverpool The Right Hon. the Earl of Sefton, K.G., Lord-Lieutenant of Lancashire Sir W. B. Forwood, J.P. Sir Henry E. Roscoe, D.C.L., F.R.S. The Principal of University College, Liverpool W. Rathbone, Esq., LL.D. W. Crookes, Esq., F.R.S., V.P.C.S. T. H. Ismay, Esq., J.P., D.L. Professor A. Liversidge, F.R.S.	Professor W. A. Herdman, F.R.S. Isaac C. Thompson, Esq., F.L.S. W. E. Willink, Esq.
SIR JOHN EVANS, K.C.B., D.C.L., LL.D., Sc.D., Treas. R.S., F.S.A., For.Sec.G.S. TORONTO, August 18, 1897.	His Excellency the Right Hon. the Earl of Aberdeen, G.C.M.G., Governor-General of the Dominion of Canada The Right Hon. Lord Rayleigh, M.A., D.C.L., F.R.S. The Right Hon. Lord Kelvin, G.C.V.O., D.C.L., LL.D., F.R.S., F.R.S.E. The Hon. Sir Wilfrid Laurier, G.C.M.G., Prime Minister of the Dominion of Canada His Honour the Lieutenant-Governor of the Province of Ontario The Hon. the Premier of the Province of Ontario The Hon. the Minister of Education for the Province of Ontario The Hon. Sir Charles Tupper, Bart., G.C.M.G., C.B., LL.D. The Hon. Sir Donald A. Smith, G.C.M.G., LL.D., High Commissioner for Canada Sir William Dawson, C.M.G., F.R.S. The Mayor of Toronto Professor J. Loudon, M.A., LL.D., President of the University of Toronto	Professor A. B. Macallum, M.B., Ph.D. B. E. Walker, Esq., F.G.S. J. S. Willison, Esq.
SIR WILLIAM CROOKES, F.R.S., V.P.C.S. BRISTOL, September 7, 1898.	The Right Hon. the Earl of Ducie, F.R.S., F.G.S. The Right Rev. the Lord Bishop of Bristol, D.D. The Right Hon. Sir Edward Fry, D.C.L., F.R.S., F.S.A. Sir F. J. Bramwell, Bart., D.C.L., LL.D., F.R.S. The Right Worshipful the Mayor of Bristol The Principal of University College, Bristol The Master of The Society of Merchant Venturers of Bristol John Beddoe, Esq., M.D., LL.D., F.R.S. Professor T. G. Bonney, D.Sc., LL.D., F.R.S., F.S.A., F.G.S.	Arthur Lee, Esq., J.P. Bertram Rogers, Esq., M.D.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
PROFESSOR SIR MICHAEL FOSTER, K.C.B., M.D., D.C.L., LL.D., Sec. R.S. DOVER, September 13, 1899.	His Grace the Lord Archbishop of Canterbury, D.D. The Most Hon. the Marquis of Salisbury, K.G., M.A., D.C.L., F.R.S. The Mayor of Dover The Major-General Commanding the South-Eastern District The Right Hon. A. Akers-Douglas, M.P. The Very Rev. F. W. Farrar, D.D., F.R.S., Dean of Canterbury Sir J. Norman Lockyer, K.C.B., F.R.S. Professor G. H. Darwin, M.A., LL.D., F.R.S., Pres. R.A.S.	E. Wollaston Knocker, Esq., C.B. W. H. Pendlebury, Esq., M.A.
PROFESSOR SIR WILLIAM TURNER, M.B., D.Sc., D.C.L., LL.D., F.R.S. BRADFORD, September 5, 1900.	The Right Hon. the Earl of Scarbrough, Lord-Lieutenant of the West Riding of Yorkshire His Grace the Duke of Devonshire, K.G., D.C.L., LL.D., F.R.S. The Most Hon. the Marquis of Ripon, K.G., G.C.S.I., D.C.L., F.R.S. The Right Rev. the Lord Bishop of Ripon, D.D. The Right Hon. Lord Masham His Worship the Mayor of Bradford The Hon. H. E. Butler, Lord of the Manor, Bradford Sir Alexander Binnie, M.Inst.C.E., F.G.S. Professor A. W. Rücker, M.A., D.Sc., Sec.R.S. Dr. T. E. Thorpe, C.B., F.R.S., Pres.C.S. Principal N. Bodington, Litt.D., Vice-Chancellor of the Victoria University Professor L. C. Miall, F.R.S.	Ramsden Bacchus, Esq. J. E. Fawcett, Esq., J.P. Frederick Stevens, Esq.
PROFESSOR A. W. RÜCKER, M.A., LL.D., D.Sc., Sec.R.S. GLASGOW, September 11, 1901.	The Right Hon. the Earl of Glasgow, G.C.M.G. The Right Hon. the Lord Blythswood, LL.D., D.L. The Right Hon. the Lord Kelvin, G.C.V.O., D.C.L., LL.D., F.R.S. Samuel Chisholm, Esq., the Hon. the Lord Provost of Glasgow Very Rev. R. Herbert Story, D.D., LL.D., the Principal of the University of Glasgow Sir John Maxwell Stirling-Maxwell, Bart., M.P., D.L. Sir Andrew Noble, K.C.B., D.C.L., F.R.S. Sir Archibald Geikie, D.C.L., LL.D., F.R.S. Sir W. T. Thiselton-Dyer, K.C.M.G., C.I.E., F.R.S. James Parker Smith, Esq., M.P., D.L. John Inglis, Esq., LL.D. Professor John Cleland, M.D., LL.D., D.Sc., F.R.S.	Sir J. D. Marwick, LL.D., D.L., F.R.S.E. Professor John Young, M.D. Professor Magnus Maclean, D.Sc., F.R.S.E.

TRUSTEES AND GENERAL OFFICERS, 1831—1902.

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1891–98 Prof. A. W. RÜCKER, F.R.S.
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GENERAL SECRETARIES.

1832–35 Rev. W. VERNON HARCOURT, F.R.S.
1835–36 Rev. W. VERNON HARCOURT, F.R.S., and F. BAILY, Esq., F.R.S.
1836–37 Rev. W. VERNON HARCOURT, F.R.S., and R. I. MURCHISON, Esq., F.R.S.
1837–39 R. I. MURCHISON, Esq., F.R.S., and Rev. G. Peacock, F.R.S.
1839–45 Sir R. I. MURCHISON, F.R.S., and Major E. SABINE, F.R.S.
1845–50 Lieut.-Colonel E. SABINE, F.R.S.
1850–52 General E. SABINE, F.R.S., and J. F. ROYLE, Esq., F.R.S.
1852–53 J. F. ROYLE, Esq., F.R.S.
1853–59 General E. SABINE, F.R.S.
1859–61 Prof. R. WALKER, F.R.S.
1861–62 W. HOPKINS, Esq., F.R.S.
1862–63 W. HOPKINS, Esq., F.R.S., and Prof. J. PHILLIPS, F.R.S.
1863–65 W. HOPKINS, Esq., F.R.S., and F. GALTON, Esq., F.R.S.
1865–66 F. GALTON, Esq., F.R.S.
1866–68 F. GALTON, Esq., F.R.S., and Dr. T. A. HIRST, F.R.S.
1868–71 Dr. T. A. HIRST, F.R.S., and Dr. T. THOMSON, F.R.S.
1871–72 Dr. T. THOMSON, F.R.S., and Capt. DOUGLAS GALTON, F.R.S.
1872–76 Capt. D. GALTON, F.R.S., and Dr. MICHAEL FOSTER, F.R.S.
1876–81 Capt. D. GALTON, F.R.S., and Dr. P. L. SCLATER, F.R.S.
1881–82 Capt. D. GALTON, F.R.S., and Prof. F. M. BALFOUR, F.R.S.
1882–83 Capt. DOUGLAS GALTON, F.R.S.
1883–95 Sir DOUGLAS GALTON, F.R.S., and A. G. VERNON HARCOURT, Esq., F.R.S.
1895–97 A. G. VERNON HARCOURT, Esq., F.R.S., and Prof. E. A. SCHÄFER, F.R.S.
1897–1900 Prof. SCHÄFER, F.R.S., and Sir W. C. ROBERTS-AUSTEN, F.R.S.
1900 Sir W. C. ROBERTS-AUSTEN, F.R.S., and Dr. D. H. SCOTT, F.R.S.

ASSISTANT GENERAL SECRETARIES.

1831 JOHN PHILLIPS, Esq., *Secretary.*
1832 Prof. J. D. FORBES, *Acting Secretary.*
1832–62 Prof. JOHN PHILLIPS, F.R.S.
1862–78 G. GRIFFITH, Esq., M.A.
1878–80 J. E. H. GORDON, Esq., B.A., *Assistant Secretary.*
G. GRIFFITH, Esq., M.A., *Acting Secretary.*
1881–85 Prof. T. G. BONNEY, F.R.S., *Secretary.*
1885–90 A. T. ATCHISON, Esq., M.A., *Secretary.*
1890 G. GRIFFITH, Esq., M.A. *Acting Secretary.*
1890 G. GRIFFITH, Esq., M.A.

Presidents and Secretaries of the Sections of the Association.

Date and Place	Presidents	Secretaries
MATHEMATICAL AND PHYSICAL SCIENCES.		
COMMITTEE OF SCIENCES, I.—MATHEMATICS AND GENERAL PHYSICS.		
1832. Oxford......	Davies Gilbert, D.C.L., F.R.S.	Rev. H. Coddington.
1833. Cambridge	Sir D. Brewster, F.R.S.	Prof. Forbes.
1834. Edinburgh	Rev. W. Whewell, F.R.S.	Prof. Forbes, Prof. Lloyd.
SECTION A.—MATHEMATICS AND PHYSICS.		
1835. Dublin......	Rev. Dr. Robinson	Prof. Sir W. R. Hamilton, Prof. Wheatstone.
1836. Bristol......	Rev. William Whewell, F.R.S.	Prof. Forbes, W. S. Harris, F. W. Jerrard.
1837. Liverpool...	Sir D. Brewster, F.R.S.	W. S. Harris, Rev. Prof. Powell, Prof. Stevelly.
1838. Newcastle	Sir J. F. W. Herschel, Bart., F.R.S.	Rev. Prof. Chevallier, Major Sabine, Prof. Stevelly.
1839. Birmingham	Rev. Prof. Whewell, F.R.S....	J. D. Chance, W. Snow Harris, Prof. Stevelly.
1840. Glasgow ...	Prof. Forbes, F.R.S............	Rev. Dr. Forbes, Prof. Stevelly, Arch. Smith.
1841. Plymouth	Rev. Prof. Lloyd, F.R.S.......	Prof. Stevelly.
1842. Manchester	Very Rev. G. Peacock, D.D., F.R.S.	Prof. M'Culloch, Prof. Stevelly, Rev. W. Scoresby.
1843. Cork.........	Prof. M'Culloch, M.R.I.A. ...	J. Nott, Prof. Stevelly.
1844. York.........	The Earl of Rosse, F.R.S. ...	Rev. Wm. Hey, Prof. Stevelly.
1845. Cambridge	The Very Rev. the Dean of Ely.	Rev. H. Goodwin, Prof. Stevelly, G. G. Stokes.
1846. Southampton.	Sir John F. W. Herschel, Bart., F.R.S.	John Drew, Dr. Stevelly, G. G. Stokes.
1847. Oxford......	Rev. Prof. Powell, M.A., F.R.S.	Rev. H. Price, Prof. Stevelly, G. G. Stokes.
1848. Swansea ...	Lord Wrottesley, F.R.S.	Dr. Stevelly, G. G. Stokes.
1849. Birmingham	William Hopkins, F.R.S.......	Prof. Stevelly, G. G. Stokes, W. Ridout Wills.
1850. Edinburgh	Prof. J. D. Forbes, F.R.S., Sec. R.S.E.	W. J. Macquorn Rankine, Prof. Smyth, Prof. Stevelly, Prof. G. G. Stokes.
1851. Ipswich ...	Rev. W. Whewell, D.D., F.R.S.	S. Jackson, W. J. Macquorn Rankine, Prof. Stevelly, Prof. G. G. Stokes.
1852. Belfast......	Prof. W. Thomson, M.A., F.R.S., F.R.S.E.	Prof. Dixon, W. J. Macquorn Rankine, Prof. Stevelly, J. Tyndall.
1853. Hull.........	The Very Rev. the Dean of Ely, F.R.S.	B. Blaydes Haworth, J. D. Sollitt, Prof. Stevelly, J. Welsh.
1854. Liverpool...	Prof. G. G. Stokes, M.A., Sec. R.S.	J. Hartnup, H. G. Puckle, Prof. Stevelly, J. Tyndall, J. Welsh.
1855. Glasgow ...	Rev. Prof. Kelland, M.A., F.R.S., F.R.S.E.	Rev. Dr. Forbes, Prof. D. Gray, Prof. Tyndall.
1856. Cheltenham	Rev. R. Walker, M.A., F.R.S.	C. Brooke, Rev. T. A. Southwood, Prof. Stevelly, Rev. J. C. Turnbull.
1857. Dublin......	Rev. T. R. Robinson, D.D., F.R.S., M.R.I.A.	Prof. Curtis, Prof. Hennessy, P. A. Ninnis, W. J. Macquorn Rankine, Prof. Stevelly.

Date and Place	Presidents	Secretaries
1858. Leeds	Rev. W. Whewell, D.D., V.P.R.S.	Rev. S. Earnshaw, J. P. Hennessy, Prof. Stevelly, H. J. S. Smith, Prof. Tyndall.
1859. Aberdeen...	The Earl of Rosse, M.A., K.P., F.R.S.	J. P. Hennessy, Prof. Maxwell, H. J. S. Smith, Prof. Stevelly.
1860. Oxford......	Rev. B. Price, M.A., F.R.S....	Rev. G. C. Bell, Rev. T. Rennison, Prof. Stevelly.
1861. Manchester	G. B. Airy, M.A., D.C.L., F.R.S.	Prof. R. B. Clifton, Prof. H. J. S. Smith, Prof. Stevelly.
1862. Cambridge	Prof. G. G. Stokes, M.A., F.R.S.	Prof. R. B. Clifton, Prof. H. J. S. Smith, Prof. Stevelly.
1863. Newcastle	Prof. W. J. Macquorn Rankine, C.E., F.R.S.	Rev. N. Ferrers, Prof. Fuller, F. Jenkin, Prof. Stevelly, Rev. C. T. Whitley.
1864. Bath.........	Prof. Cayley, M.A., F.R.S., F.R.A.S.	Prof. Fuller, F. Jenkin, Rev. G. Buckle, Prof. Stevelly.
1865. Birmingham	W. Spottiswoode, M.A., F.R.S., F.R.A.S.	Rev. T. N. Hutchinson, F. Jenkin, G. S. Mathews, Prof. H. J. S. Smith, J. M. Wilson.
1866. Nottingham	Prof. Wheatstone, D.C.L., F.R.S.	Fleeming Jenkin, Prof. H. J. S. Smith, Rev. S. N. Swann.
1867. Dundee ...	Prof. Sir W. Thomson, D.C.L., F.R.S.	Rev. G. Buckle, Prof. G. C. Foster, Prof. Fuller, Prof. Swan.
1868. Norwich ...	Prof. J. Tyndall, LL.D., F.R.S.	Prof. G. C. Foster, Rev. R. Harley, R. B. Hayward.
1869. Exeter	Prof. J. J. Sylvester, LL.D., F.R.S.	Prof. G. C. Foster, R. B. Hayward, W. K. Clifford.
1870. Liverpool...	J. Clerk Maxwell, M.A., LL.D., F.R.S.	Prof. W. G. Adams, W. K. Clifford, Prof. G. C. Foster, Rev. W. Allen Whitworth.
1871. Edinburgh	Prof. P. G. Tait, F.R.S.E.	Prof. W. G. Adams, J. T. Bottomley, Prof. W. K. Clifford, Prof. J. D. Everett, Rev. R. Harley.
1872. Brighton.	W. De La Rue, D.C.L., F.R.S.	Prof. W. K. Clifford, J. W. L. Glaisher, Prof. A. S. Herschel, G. F. Rodwell.
1873. Bradford ...	Prof. H. J. S. Smith, F.R.S. .	Prof. W. K. Clifford, Prof. Forbes, J. W. L. Glaisher, Prof. A. S. Herschel.
1874. Belfast......	Rev. Prof. J. H. Jellett, M.A., M.R.I.A.	J. W. L. Glaisher, Prof. Herschel, Randal Nixon, J. Perry, G. F. Rodwell.
1875. Bristol	Prof. Balfour Stewart, M.A., LL.D., F.R.S.	Prof. W. F. Barrett, J. W. L. Glaisher, C. T. Hudson, G. F. Rodwell.
1876. Glasgow	Prof. Sir W. Thomson, M.A., D.C.L., F.R.S.	Prof. W. F. Barrett, J. T. Bottomley, Prof. G. Forbes, J. W. L. Glaisher, T. Muir.
1877. Plymouth...	Prof. G. C. Foster, B.A., F.R.S., Pres. Physical Soc.	Prof. W. F. Barrett, J. T. Bottomley, J. W. L. Glaisher, F. G. Landon.
1878. Dublin.. ..	Rev. Prof. Salmon, D.D., D.C.L., F.R.S.	Prof. J. Casey, G. F. Fitzgerald, J. W. L. Glaisher, Dr. O. J. Lodge.
1879. Sheffield ...	George Johnstone Stoney, M.A., F.R.S.	A. H. Allen, J. W. L. Glaisher, Dr. O. J. Lodge, D. MacAlister.
1880. Swansea ...	Prof. W. Grylls Adams, M.A., F.R.S.	W. E. Ayrton, J. W. L. Glaisher, Dr. O. J. Lodge, D. MacAlister.
1881. York.........	Prof. Sir W. Thomson, M.A., LL.D., D.C.L., F.R.S.	Prof. W. E. Ayrton, Dr. O. J. Lodge, D. MacAlister, Rev. W. Routh.
1882. Southampton.	Rt. Hon. Prof. Lord Rayleigh, M.A., F.R.S.	W. M. Hicks, Dr. O. J. Lodge, D. MacAlister, Rev. G. Richardson.
1883. Southport	Prof. O. Henrici, Ph.D., F.R.S.	W. M. Hicks, Prof. O. J. Lodge, D. MacAlister, Prof. R. C. Rowe.
1884. Montreal ...	Prof. Sir W. Thomson, M.A., LL.D., D.C.L., F.R.S.	C. Carpmael, W. M. Hicks, A. Johnson, O. J. Lodge, D. MacAlister.

Date and Place	Presidents	Secretaries
1885. Aberdeen...	Prof. G. Chrystal, M.A., F.R.S.E.	R. E. Baynes, R. T. Glazebrook, Prof. W. M. Hicks, Prof. W. Ingram.
1886. Birmingham	Prof. G. H. Darwin, M.A., LL.D., F.R.S.	R. E. Baynes, R. T. Glazebrook, Prof. J. H. Poynting, W. N. Shaw.
1887. Manchester	Prof. Sir R. S. Ball, M.A., LL.D., F.R.S.	R. E. Baynes, R. T. Glazebrook, Prof. H. Lamb, W. N. Shaw.
1888. Bath.........	Prof. G. F. Fitzgerald, M.A., F.R.S.	R. E. Baynes, R. T. Glazebrook, A. Lodge, W. N. Shaw.
1889. Newcastle-upon-Tyne	Capt. W. de W. Abney, C.B., R.E., F.R.S.	R. E. Baynes, R. T. Glazebrook, A. Lodge, W. N. Shaw, H. Stroud.
1890. Leeds	J. W. L. Glaisher, Sc.D., F.R.S., V.P.R.A.S.	R. T. Glazebrook, Prof. A. Lodge, W. N. Shaw, Prof. W. Stroud.
1891. Cardiff......	Prof. O. J. Lodge, D.Sc., LL.D., F.R.S.	R. E. Baynes, J. Larmor, Prof. A. Lodge, Prof. A. L. Selby.
1892. Edinburgh	Prof. A. Schuster, Ph.D., F.R.S., F.R.A.S.	R. E. Baynes, J. Larmor, Prof. A. Lodge, Dr. W. Peddie.
1893. Nottingham	R. T. Glazebrook, M.A., F.R.S.	W. T. A. Emtage, J. Larmor, Prof. A. Lodge, Dr. W. Peddie.
1894. Oxford	Prof. A. W. Rücker, M.A., F.R.S.	Prof. W. H. Heaton, Prof. A. Lodge, J. Walker.
1895. Ipswich ...	Prof. W. M. Hicks, M.A., F.R.S.	Prof. W. H. Heaton, Prof. A. Lodge, G. T. Walker, W. Watson.
1896. Liverpool...	Prof. J. J. Thomson, M.A., D.Sc., F.R.S.	Prof. W. H. Heaton, J. L. Howard, Prof. A. Lodge, G. T. Walker, W. Watson.
1897. Toronto ...	Prof. A. R. Forsyth, M.A., F.R.S.	Prof. W. H. Heaton, J. C. Glashan, J. L. Howard, Prof. J. C. McLennan.
1898. Bristol	Prof. W. E. Ayrton, F.R.S. ...	A. P. Chattock, J. L. Howard, C. H. Lees, W. Watson, E. T. Whittaker.
1899. Dover	Prof. J. H. Poynting, F.R.S.	J. L. Howard, C. H. Lees, W. Watson, E. T. Whittaker.
1900. Bradford ...	Dr. J. Larmor, F.R.S.	P. H. Cowell, A. Fowler, C. H. Lees, C. J. L. Wagstaffe, W. Watson, E. T. Whittaker.
1901. Glasgow ...	Major P. A. MacMahon, F.R.S.	H. S. Carslaw, C. H. Lees, W. Stewart, Prof. L. R. Wilberforce.

CHEMICAL SCIENCE.

COMMITTEE OF SCIENCES, II.—CHEMISTRY, MINERALOGY.

1832. Oxford......	John Dalton, D.C.L., F.R.S.	James F. W. Johnston.
1833. Cambridge	John Dalton, D.C.L., F.R.S.	Prof. Miller.
1834. Edinburgh	Dr. Hope..........................	Mr. Johnston, Dr. Christison.

SECTION B.—CHEMISTRY AND MINERALOGY.

1835. Dublin......	Dr. T. Thomson, F.R.S.	Dr. Apjohn, Prof. Johnston.
1836. Bristol......	Rev. Prof. Cumming	Dr. Apjohn, Dr. C. Henry, W. Herapath.
1837. Liverpool...	Michael Faraday, F.R.S.......	Prof. Johnston, Prof. Miller, Dr. Reynolds.
1838. Newcastle	Rev. William Whewell, F.R.S.	Prof. Miller, H. L. Pattinson, Thomas Richardson.
1839. Birmingham	Prof. T. Graham, F.R.S.	Dr. Golding Bird, Dr. J. B. Melson.
1840. Glasgow ...	Dr. Thomas Thomson, F.R.S.	Dr. R. D. Thomson, Dr. T. Clark, Dr. L. Playfair.
1841. Plymouth...	Dr. Daubeny, F.R.S.	J. Prideaux, R. Hunt, W. M. Tweedy.
1842. Manchester	John Dalton, D.C.L., F.R.S.	Dr. L. Playfair, R. Hunt, J. Graham.
1843. Cork.........	Prof. Apjohn, M.R.I.A.........	R. Hunt, Dr. Sweeny.
1844. York.........	Prof. T. Graham, F.R.S.	Dr. L. Playfair, E. Solly, T. H. Barker.
1845. Cambridge	Rev. Prof. Cumming	R. Hunt, J. P. Joule, Prof. Miller, E. Solly.

Date and Place	Presidents	Secretaries
1846. Southampton.	Michael Faraday, D.C.L., F.R.S.	Dr. Miller, R. Hunt, W. Randall.
1847. Oxford......	Rev. W. V. Harcourt, M.A., F.R.S.	B. C. Brodie, R. Hunt, Prof. Solly.
1848. Swansea ...	Richard Phillips, F.R.S.	T. H. Henry, R. Hunt, T. Williams.
1849. Birmingham	John Percy, M.D., F.R.S.......	R. Hunt, G. Shaw.
1850. Edinburgh	Dr. Christison, V.P.R.S.E. ...	Dr. Anderson, R. Hunt, Dr. Wilson.
1851. Ipswich ...	Prof. Thomas Graham, F.R.S.	T. J. Pearsall, W. S. Ward.
1852. Belfast......	Thomas Andrews, M.D., F.R.S.	Dr. Gladstone, Prof. Hodges, Prof. Ronalds.
1853. Hull.	Prof. J. F. W. Johnston, M.A., F.R.S.	H. S. Blundell, Prof. R. Hunt, T. J. Pearsall.
1854. Liverpool	Prof. W. A. Miller, M.D., F.R.S.	Dr. Edwards, Dr. Gladstone, Dr. Price.
1855. Glasgow ...	Dr. Lyon Playfair, C.B., F.R.S.	Prof. Frankland, Dr. H. E. Roscoe.
1856. Cheltenham	Prof. B. C. Brodie, F.R.S. ...	J. Horsley, P. J. Worsley, Prof. Voelcker.
1857. Dublin......	Prof. Apjohn, M.D., F.R.S., M.R.I.A.	Dr. Davy, Dr. Gladstone, Prof. Sullivan.
1858. Leeds	Sir J. F. W. Herschel, Bart., D.C.L.	Dr. Gladstone, W. Odling, R. Reynolds.
1859. Aberdeen...	Dr. Lyon Playfair, C.B., F.R.S.	J. S. Brazier, Dr. Gladstone, G. D. Liveing, Dr. Odling.
1860. Oxford......	Prof. B. C. Brodie, F.R.S......	A. Vernon Harcourt, G. D. Liveing, A. B. Northcote.
1861. Manchester	Prof. W. A. Miller, M.D., F.R.S.	A. Vernon Harcourt, G. D. Liveing.
1862. Cambridge	Prof. W. H. Miller, M.A., F.R.S.	H. W. Elphinstone, W. Odling, Prof. Roscoe.
1863. Newcastle	Dr. Alex. W. Williamson, F.R.S.	Prof. Liveing, H. L. Pattinson, J. C. Stevenson.
1864. Bath.	W. Odling, M.B., F.R.S..	A. V. Harcourt, Prof. Liveing, R. Biggs.
1865. Birmingham	Prof. W. A. Miller, M.D., V.P.R.S.	A. V. Harcourt, H. Adkins, Prof. Wanklyn, A. Winkler Wills.
1866. Nottingham	H. Bence Jones, M.D., F.R.S.	J. H. Atherton, Prof. Liveing, W. J. Russell, J. White.
1867. Dundee ...	Prof. T. Anderson, M.D., F.R.S.E.	A. Crum Brown, Prof. G. D. Liveing, W. J. Russell.
1868. Norwich ...	Prof. E. Frankland, F.R.S.	Dr. A. Crum Brown, Dr. W. J. Russell, F. Sutton.
1869. Exeter	Dr. H. Debus, F.R.S.	Prof. A. Crum Brown, Dr. W. J. Russell, Dr. Atkinson.
1870. Liverpool...	Prof. H. E. Roscoe, B.A., F.R.S.	Prof. A. Crum Brown, A. E. Fletcher, Dr. W. J. Russell.
1871. Edinburgh	Prof. T. Andrews, M.D., F.R.S.	J. Y. Buchanan, W. N. Hartley, T. E. Thorpe.
1872. Brighton ...	Dr. J. H. Gladstone, F.R.S....	Dr. Mills, W. Chandler Roberts, Dr. W. J. Russell, Dr. T. Wood.
1873. Bradford...	Prof. W. J. Russell, F.R.S....	Dr. Armstrong, Dr. Mills, W. Chandler Roberts, Dr. Thorpe.
1874. Belfast......	Prof. A. Crum Brown, M.D., F.R.S.E.	Dr. T. Cranstoun Charles, W. Chandler Roberts, Prof. Thorpe.
1875. Bristol	A. G. Vernon Harcourt, M.A., F.R.S.	Dr. H. E. Armstrong, W. Chandler Roberts, W. A. Tilden.
1876. Glasgow ...	W. H. Perkin, F.R.S.	W. Dittmar, W. Chandler Roberts, J. M. Thomson, W. A. Tilden.
1877. Plymouth...	F. A. Abel, F.R.S..............	Dr. Oxland, W. Chandler Roberts, J. M. Thomson.
Dublin	Prof. Maxwell Simpson, M.D., F.R.S.	W. Chandler Roberts, J. M. Thomson, Dr. C. R. Tichborne, T. Wills.

Date and Place	Presidents	Secretaries
1879. Sheffield ...	Prof. Dewar, M.A., F.R.S. ...	H. S. Bell, W. Chandler Roberts, J. M. Thomson.
1880. Swansea ...	Joseph Henry Gilbert, Ph.D., F.R.S.	P. P. Bedson, H. B. Dixon, W. R. E. Hodgkinson, J. M. Thomson.
1881. York.........	Prof. A. W. Williamson, F.R.S.	P. P. Bedson, H. B. Dixon, T. Gough.
1882. Southampton.	Prof. G. D. Liveing, M.A., F.R.S.	P. Phillips Bedson, H. B. Dixon, J. L. Notter.
1883. Southport	Dr. J. H. Gladstone, F.R.S...	Prof. P. Phillips Bedson, H. B. Dixon, H. Forster Morley.
1884. Montreal ...	Prof. Sir H. E. Roscoe, Ph.D., LL.D., F.R.S.	Prof. P. Phillips Bedson, H. B. Dixon, T. McFarlane, Prof. W. H. Pike.
1885. Aberdeen...	Prof. H. E. Armstrong, Ph.D., F.R.S., Sec. C.S.	Prof. P. Phillips Bedson, H. B. Dixon, H. Forster Morley, Dr. W. J. Simpson.
1886. Birmingham	W. Crookes, F.R.S., V.P.C.S.	P. P. Bedson, H. B. Dixon, H. F. Morley, W. W. J. Nicol, C. J. Woodward.
1887. Manchester	Dr. E. Schunck, F.R.S.	Prof. P. Phillips Bedson, H. Forster Morley, W. Thomson.
1888. Bath.........	Prof. W. A. Tilden, D.Sc., F.R.S., V.P.C.S.	Prof. H. B. Dixon, H. Forster Morley, R. E. Moyle, W. W. J. Nicol.
1889. Newcastle-upon-Tyne	Sir I. Lowthian Bell, Bart., D.C.L., F.R.S.	H. Forster Morley, D. H. Nagel, W. W. J. Nicol, H. L. Pattinson, jun.
1890. Leeds	Prof. T. E. Thorpe, B.Sc., Ph.D., F.R.S., Treas. C.S.	C. H. Bothamley, H. Forster Morley, D. H. Nagel, W. W. J. Nicol.
1891. Cardiff......	Prof. W. C. Roberts-Austen, C.B., F.R.S.	C. H. Bothamley, H. Forster Morley, W. W. J. Nicol, G. S. Turpin.
1892. Edinburgh	Prof. H. McLeod, F.R.S.......	J. Gibson, H. Forster Morley, D. H. Nagel, W. W. J. Nicol.
1893. Nottingham	Prof. J. Emerson Reynolds, M.D., D.Sc., F.R.S.	J. B. Coleman, M. J. R. Dunstan, D. H. Nagel, W. W. J. Nicol.
1894. Oxford......	Prof. H. B. Dixon, M.A., F.R.S.	A. Colefax, W. W. Fisher, Arthur Harden, H. Forster Morley.

SECTION B (*continued*).—CHEMISTRY.

1895. Ipswich ...	Prof. R. Meldola, F.R.S.	E. H. Fison, Arthur Harden, C. A. Kohn, J. W. Rodger.
1896. Liverpool...	Dr. Ludwig Mond, F.R.S.	Arthur Harden, C. A. Kohn.
1897 Toronto ...	Prof. W. Ramsay, F.R.S.......	Prof. W. H. Ellis, A. Harden, C. A. Kohn, Prof. R. F. Ruttan.
1898. Bristol	Prof. F. R. Japp, F.R.S.	C. A. Kohn, F. W. Stoddart, T. K. Rose.
1899. Dover	Horace T. Brown, F.R.S.......	A. D. Hall, C. A. Kohn, T. K. Rose, Prof. W. P. Wynne.
1900. Bradford ...	Prof. W. H. Perkin, F.R.S. ...	W. M. Gardner, F. S. Kipping, W. J. Pope, T. K. Rose.
1901. Glasgow ...	Prof. Percy F. Frankland, F.R.S.	W. C. Anderson, G. G. Henderson, W. J. Pope, T. K. Rose.

GEOLOGICAL (AND, UNTIL 1851, GEOGRAPHICAL) SCIENCE.

COMMITTEE OF SCIENCES, III.—GEOLOGY AND GEOGRAPHY.

1832. Oxford......	R. I. Murchison, F.R.S.	John Taylor.
1833. Cambridge.	G. B. Greenough, F.R.S.	W. Lonsdale, John Phillips.
1834. Edinburgh .	Prof. Jameson	J. Phillips, T. J. Torrie, Rev. J. Yates.

SECTION C.—GEOLOGY AND GEOGRAPHY.

1835. Dublin......	R. J. Griffith	Captain Portlock, T. J. Torrie.
1836. Bristol	Rev. Dr. Buckland, F.R.S.—*Geog.*, R. I. Murchison, F.R.S.	William Sanders, S. Stutchbury, T. J. Torrie.
1837. Liverpool...	Rev. Prof. Sedgwick, F.R.S.—*Geog.*, G. B. Greenough, F.R.S.	Captain Portlock, R. Hunter.—*Geography*, Capt. H. M. Denham, R.N.

Date and Place	Presidents	Secretaries
1838. Newcastle..	C. Lyell, F.R.S., V.P.G.S.—*Geography*, Lord Prudhoe.	W. C. Trevelyan, Capt. Portlock.—*Geography*, Capt. Washington.
1839. Birmingham	Rev. Dr. Buckland, F.R.S.—*Geog.*, G.B. Greenough, F.R.S.	George Lloyd, M.D., H. E. Strickland, Charles Darwin.
1840. Glasgow ...	Charles Lyell, F.R.S.—*Geog.*, G. B. Greenough, F.R.S.	W. J. Hamilton, D. Milne, H. Murray, H. E. Strickland, J. Scoular.
1841. Plymouth...	H. T. De la Beche, F.R.S. ...	W. J. Hamilton, Edward Moore, M.D., R. Hutton.
1842. Manchester	R. I. Murchison, F.R.S.	E. W. Binney, R. Hutton, Dr. R. Lloyd, H. E. Strickland.
1843. Cork.........	Richard E. Griffith, F.R.S. ...	F. M. Jennings, H. E. Strickland.
1844. York.........	Henry Warburton, Pres. G. S.	Prof. Ansted, E. H. Bunbury.
1845. Cambridge.	Rev. Prof. Sedgwick, M.A. F.R.S.	Rev. J. C. Cumming, A. C. Ramsay, Rev. W. Thorp.
1846. Southampton.	Leonard Horner, F.R.S.	Robert A. Austen, Dr. J. H. Norton, Prof. Oldham, Dr. C. T. Beke.
1847. Oxford......	Very Rev. Dr. Buckland, F.R.S.	Prof. Ansted, Prof. Oldham, A. C. Ramsay, J. Ruskin.
1848. Swansea ...	Sir H. T. De la Beche, F.R.S.	S. Benson, Prof. Oldham, Prof. Ramsay
1849. Birmingham	Sir Charles Lyell, F.R.S.......	J. B. Jukes, Prof. Oldham, A. C. Ramsay.
1850. Edinburgh[1]	Sir Roderick I. Murchison, F.R.S.	A. Keith Johnston, Hugh Miller, Prof. Nicol.

SECTION C (*continued*).—GEOLOGY.

1851. Ipswich ...	William Hopkins, M.A., F.R.S.	C. J. F. Bunbury, G. W. Ormerod, Searles Wood.
1852. Belfast......	Lieut.-Col. Portlock, R.E., F.R.S.	James Bryce, James MacAdam, Prof. M'Coy, Prof. Nicol.
1853. Hull.........	Prof. Sedgwick, F.R.S.........	Prof. Harkness, William Lawton.
1854. Liverpool..	Prof. Edward Forbes, F.R.S.	John Cunningham, Prof. Harkness, G. W. Ormerod, J. W. Woodall.
1855. Glasgow ...	Sir R. I. Murchison, F.R.S....	J. Bryce, Prof. Harkness, Prof. Nicol.
1856. Cheltenham	Prof. A. C. Ramsay, F.R.S....	Rev. P. B. Brodie, Rev. R. Hepworth, Edward Hull, J. Scougall, T. Wright.
1857. Dublin......	The Lord Talbot de Malahide	Prof. Harkness, G. Sanders, R. H. Scott.
1858. Leeds	William Hopkins, M.A., F.R.S.	Prof. Nicol, H. C. Sorby, E. W. Shaw.
1859. Aberdeen...	Sir Charles Lyell, LL.D., D.C.L., F.R.S.	Prof. Harkness, Rev. J. Longmuir H. C. Sorby.
1860. Oxford......	Rev. Prof. Sedgwick, F.R.S...	Prof. Harkness, E. Hull, J. W. Woodall.
1861. Manchester	Sir R. I. Murchison, D.C.L., LL.D., F.R.S.	Prof. Harkness, Edward Hull, T. Rupert Jones, G. W. Ormerod.
1862. Cambridge	J. Beete Jukes, M.A., F.R.S.	Lucas Barrett, Prof. T. Rupert Jones, H. C. Sorby.
1863. Newcastle	Prof. Warington W. Smyth, F.R.S., F.G.S.	E. F. Boyd, John Daglish, H. C. Sorby, Thomas Sopwith.
1864. Bath	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	W. B. Dawkins, J. Johnston, H. C. Sorby, W. Pengelly.
1865. Birmingham	Sir R. I. Murchison, Bart., K.C.B.	Rev. P. B. Brodie, J. Jones, Rev. E. Myers, H. C. Sorby, W. Pengelly.
1866. Nottingham	Prof. A. C. Ramsay, LL.D., F.R.S.	R. Etheridge, W. Pengelly, T. Wilson, G. H. Wright.
1867. Dundee ...	Archibald Geikie, F.R.S.......	E. Hull, W. Pengelly, H. Woodward.
1868. Norwich ...	R. A. C. Godwin-Austen, F.R.S., F.G.S.	Rev. O. Fisher, Rev. J. Gunn, W. Pengelly, Rev. H. H. Winwood.

[1] Geography was constituted a separate Section, see page lxv.

Date and Place	Presidents	Secretaries
1869. Exeter	Prof. R. Harkness, F.R.S., F.G.S.	W. Pengelly, W. Boyd Dawkins, Rev. H. H. Winwood.
1870. Liverpool...	Sir Philip de M.Grey Egerton, Bart., M.P., F.R.S.	W. Pengelly, Rev. H. H. Winwood, W. Boyd Dawkins, G. H. Morton.
1871. Edinburgh	Prof. A. Geikie, F.R.S., F.G.S.	R. Etheridge, J. Geikie, T. McKenny Hughes, L. C. Miall.
1872. Brighton ...	R. A. C. Godwin-Austen, F.R.S., F.G.S.	L. C. Miall, George Scott, William Topley, Henry Woodward.
1873. Bradford ...	Prof. J. Phillips, F.R.S.	L.C.Miall,R.H.Tiddeman,W.Topley.
1874. Belfast......	Prof. Hull, M.A., F.R.S., F.G.S.	F. Drew, L. C. Miall, R. G. Symes, R. H. Tiddeman.
1875. Bristol	Dr.T.Wright,F.R.S.E.,F.G.S.	L. C. Miall,E. B. Tawney,W. Topley.
1876. Glasgow ...	Prof. John Young, M.D.	J.Armstrong,F.W.Rudler,W.Topley.
1877. Plymouth...	W. Pengelly, F.R.S., F.G.S.	Dr. Le Neve Foster, R. H. Tiddeman, W. Topley.
1878. Dublin......	John Evans, D.C.L., F.R.S., F.S.A., F.G.S.	E. T. Hardman, Prof. J. O'Reilly, R. H. Tiddeman.
1879. Sheffield ...	Prof. P. M. Duncan, F.R.S.	W. Topley, G. Blake Walker.
1880. Swansea ...	H. C. Sorby, F.R.S., F.G.S....	W. Topley, W. Whitaker.
1881. York.........	A. C. Ramsay, LL.D., F.R.S., F.G.S.	J. E. Clark, W. Keeping, W. Topley, W. Whitaker.
1882. Southampton.	R. Etheridge, F.R.S., F.G.S.	T. W. Shore, W. Topley, E. Westlake, W. Whitaker.
1883. Southport	Prof. W. C. Williamson, LL.D., F.R.S.	R. Betley, C. E. De Rance, W. Topley, W. Whitaker.
1884. Montreal ...	W. T. Blanford, F.R.S., Sec. G.S.	F. Adams, Prof. E. W. Claypole, W. Topley, W. Whitaker.
1885. Aberdeen ...	Prof. J. W. Judd, F.R.S., Sec. G.S.	C. E. De Rance, J. Horne, J. J. H. Teall, W. Topley.
1886. Birmingham	Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S.	W. J. Harrison, J. J. H. Teall, W. Topley, W. W. Watts.
1887. Manchester	Henry Woodward, LL.D., F.R.S., F.G.S.	J. E. Marr, J. J. H. Teall, W. Topley, W. W. Watts.
1888. Bath.	Prof. W. Boyd Dawkins, M.A., F.R.S., F.G.S.	Prof. G. A. Lebour, W. Topley, W. W. Watts, H. B. Woodward.
1889. Newcastle-upon-Tyne	Prof. J. Geikie, LL.D., D.C.L., F.R.S., F.G.S.	Prof. G. A. Lebour, J. E. Marr, W. W. Watts, H. B. Woodward.
1890. Leeds	Prof. A. H. Green, M.A., F.R.S., F.G.S.	J. E. Bedford, Dr. F. H. Hatch, J. E. Marr, W. W. Watts.
1891. Cardiff	Prof. T. Rupert Jones, F.R.S., F.G.S.	W. Galloway, J. E. Marr, Clement Reid, W. W. Watts.
1892. Edinburgh	Prof. C. Lapworth, LL.D., F.R.S., F.G.S.	H. M. Cadell, J. E. Marr, Clement Reid, W. W. Watts.
1893. Nottingham	J. J. H. Teall, M.A., F.R.S., F.G.S.	J. W. Carr, J. E. Marr, Clement Reid, W. W. Watts.
1894. Oxford......	L. Fletcher, M.A., F.R.S. ...	F. A. Bather, A. Harker, Clement Reid, W. W. Watts.
1895. Ipswich ...	W. Whitaker, B.A., F.R.S. ...	F. A. Bather, G. W. Lamplugh, H. A. Miers, Clement Reid.
1896. Liverpool...	J. E. Marr, M.A., F.R.S.......	J. Lomas, Prof. H. A. Miers, C. Reid.
1897. Toronto ...	Dr. G. M. Dawson, C.M.G., F.R.S.	Prof. A. P. Coleman, G. W. Lamplugh, Prof. H. A. Miers.
1898. Bristol	W. H. Hudleston, F.R.S.......	G. W. Lamplugh, Prof. H. A. Miers, H. Pentecost.
1899. Dover	Sir Arch. Geikie, F.R.S.	J. W. Gregory, G. W. Lamplugh, Capt. McDakin, Prof. H. A. Miers.
1900. Bradford ...	Prof. W. J. Sollas, F.R.S.	H. L. Bowman, Rev. W. Lower Carter, G. W. Lamplugh, H. W. Monckton.
1901. Glasgow ...	John Horne, F.R.S.	H. L. Bowman, H. W. Monckton.

Date and Place	Presidents	Secretaries

BIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, IV.—ZOOLOGY, BOTANY, PHYSIOLOGY, ANATOMY.

1832. Oxford......	Rev. P. B. Duncan, F.G.S. ...	Rev. Prof. J. S. Henslow.
1833. Cambridge[1]	Rev. W. L. P. Garnons, F.L.S.	C. C. Babington, D. Don.
1834. Edinburgh.	Prof. Graham....................	W. Yarrell, Prof. Burnett.

SECTION D.—ZOOLOGY AND BOTANY.

1835. Dublin......	Dr. Allman......................	J. Curtis, Dr. Litton.
1836. Bristol......	Rev. Prof. Henslow	J. Curtis, Prof. Don, Dr. Riley, S. Rootsey.
1837. Liverpool...	W. S. MacLeay.................	C. C. Babington, Rev. L. Jenyns, W. Swainson.
1838. Newcastle	Sir W. Jardine, Bart.	J. E. Gray, Prof. Jones, R. Owen, Dr. Richardson.
1839. Birmingham	Prof. Owen, F.R.S.	E. Forbes, W. Ick, R. Patterson.
1840. Glasgow ...	Sir W. J. Hooker, LL.D.......	Prof. W. Couper, E. Forbes, R. Patterson.
1841. Plymouth...	John Richardson, M.D., F.R.S.	J. Couch, Dr. Lankester, R. Patterson.
1842. Manchester.	Hon. and Very Rev. W. Herbert, LL.D., F.L.S.	Dr. Lankester, R. Patterson, J. A. Turner.
1843. Cork..	William Thompson, F.L.S....	G. J. Allman, Dr. Lankester, R. Patterson.
1844. York..	Very Rev. the Dean of Manchester.	Prof. Allman, H. Goodsir, Dr. King, Dr. Lankester.
1845. Cambridge	Rev. Prof. Henslow, F.L.S....	Dr. Lankester, T. V. Wollaston.
1846. Southampton.	Sir J. Richardson, M.D., F.R.S.	Dr. Lankester, T. V. Wollaston, H. Wooldridge.
1847. Oxford......	H. E. Strickland, M.A., F.R.S.	Dr. Lankester, Dr. Melville, T. V. Wollaston.

SECTION D (*continued*).—ZOOLOGY AND BOTANY, INCLUDING PHYSIOLOGY.

[For the Presidents and Secretaries of the Anatomical and Physiological Subsections and the temporary Section E of Anatomy and Medicine, see p. lxiv.]

1848. Swansea ...	L. W. Dillwyn, F.R.S.........	Dr. R. Wilbraham Falconer, A. Henfrey, Dr. Lankester.
1849. Birmingham	William Spence, F.R.S.	Dr. Lankester, Dr. Russell.
1850. Edinburgh	Prof. Goodsir, F.R.S. L. & E.	Prof. J. H. Bennett, M.D., Dr. Lankester, Dr. Douglas Maclagan.
1851. Ipswich ...	Rev. Prof. Henslow, M.A., F.R.S.	Prof. Allman, F. W. Johnston, Dr. E. Lankester.
1852. Belfast......	W. Ogilby	Dr. Dickie, George C. Hyndman, Dr. Edwin Lankester.
1853. Hull.	C. C. Babington, M.A., F.R.S.	Robert Harrison, Dr. E. Lankester.
1854. Liver[illegible]	Prof. Balfour, M.D., F.R.S....	Isaac Byerley, Dr. E. Lankester.
1855. Glas[illegible]	Rev. Dr. Fleeming, F.R.S.E.	William Keddie, Dr. Lankester.
1856. Cheltenham	Thomas Bell, F.R.S., Pres.L.S.	Dr. J. Abercrombie, Prof. Buckman, Dr. Lankester.
1857. Dublin......	Prof. W. H. Harvey, M.D., F.R.S.	Prof. J. R. Kinahan, Dr. E. Lankester, Robert Patterson, Dr. W. E. Steele.

[1] At this Meeting Physiology and Anatomy were made a separate Committee, for Presidents and Secretaries of which see p. lxiv.

Date and Place	Presidents	Secretaries
1858. Leeds	C. C. Babington, M.A., F.R.S.	Henry Denny, Dr. Heaton, Dr. E. Lankester, Dr. E. Perceval Wright.
1859. Aberdeen...	Sir W. Jardine, Bart., F.R.S.E.	Prof. Dickie, M.D., Dr. E. Lankester, Dr. Ogilvy.
1860. Oxford......	Rev. Prof. Henslow, F.L.S....	W. S. Church, Dr. E. Lankester, P. L. Sclater, Dr. E. Perceval Wright.
1861. Manchester	Prof. C. C. Babington, F.R.S.	Dr. T. Alcock, Dr. E. Lankester, Dr. P. L. Sclater, Dr. E. P. Wright.
1862. Cambridge	Prof. Huxley, F.R.S.	Alfred Newton, Dr. E. P. Wright.
1863. Newcastle	Prof. Balfour, M.D., F.R.S....	Dr. E. Charlton, A. Newton, Rev. H. B. Tristram, Dr. E. P. Wright.
1864. Bath.........	Dr. John E. Gray, F.R.S. ...	H. B. Brady, C. E. Broom, H. T. Stainton, Dr. E. P. Wright.
1865. Birmingham[1]	T. Thomson, M.D., F.R.S. ...	Dr. J. Anthony, Rev. C. Clarke, Rev. H. B. Tristram, Dr. E. P. Wright.

SECTION D (*continued*).—BIOLOGY.

1866. Nottingham	Prof. Huxley, F.R.S.—*Dep. of Physiol.*, Prof. Humphry, F.R.S.—*Dep. of Anthropol.*, A. R. Wallace.	Dr. J. Beddard, W. Felkin, Rev. H. B. Tristram, W. Turner, E. B. Tylor, Dr. E. P. Wright.
1867. Dundee ...	Prof. Sharpey, M.D., Sec. R.S.—*Dep. of Zool. and Bot.*, George Busk, M.D., F.R.S.	C. Spence Bate, Dr. S. Cobbold, Dr. M. Foster, H. T. Stainton, Rev. H. B. Tristram, Prof. W. Turner.
1868. Norwich ...	Rev. M. J. Berkeley, F.L.S.—*Dep. of Physiology*, W. H. Flower, F.R.S.	Dr. T. S. Cobbold, G. W. Firth, Dr. M. Foster, Prof. Lawson, H. T. Stainton, Rev. Dr. H. B. Tristram, Dr. E. P. Wright.
1869. Exeter	George Busk, F.R.S., F.L.S.—*Dep. of Bot. and Zool.*, C. Spence Bate, F.R.S.—*Dep. of Ethno.*, E. B. Tylor.	Dr. T. S. Cobbold, Prof. M. Foster, E. Ray Lankester, Prof. Lawson, H. T. Stainton, Rev. H. B. Tristram.
1870. Liverpool...	Prof. G. Rolleston, M.A., M.D., F.R.S., F.L.S.—*Dep. of Anat. and Physiol.*, Prof. M. Foster, M.D., F.L.S.—*Dep. of Ethno.*, J. Evans, F.R.S.	Dr. T. S. Cobbold, Sebastian Evans, Prof. Lawson, Thos. J. Moore, H. T. Stainton, Rev. H. B. Tristram, C. Staniland Wake, E. Ray Lankester.
1871. Edinburgh..	Prof. Allen Thomson, M.D., F.R.S.—*Dep. of Bot. and Zool.*, Prof. Wyville Thomson, F.R.S.—*Dep. of Anthropol.*, Prof. W. Turner, M.D.	Dr. T. R. Fraser, Dr. Arthur Gamgee, E. Ray Lankester, Prof. Lawson, H. T. Stainton, C. Staniland Wake, Dr. W. Rutherford, Dr. Kelburne King.
1872. Brighton ...	Sir J. Lubbock, Bart., F.R.S.—*Dep. of Anat. and Physiol.*, Dr. Burdon Sanderson, F.R.S.—*Dep. of Anthropol.*, Col. A. Lane Fox, F.G.S.	Prof. Thiselton-Dyer, H. T. Stainton, Prof. Lawson, F. W. Rudler, J. H. Lamprey, Dr. Gamgee, E. Ray Lankester, Dr. Pye-Smith.
1873. Bradford ...	Prof. Allman, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Rutherford, M.D.—*Dep. of Anthropol.*, Dr. Beddoe, F.R.S.	Prof. Thiselton-Dyer, Prof. Lawson, R. M'Lachlan, Dr. Pye-Smith, E. Ray Lankester, F. W. Rudler, J. H. Lamprey.

[1] The title of Section D was changed to Biology.

Date and Place	Presidents	Secretaries
1874. Belfast.	Prof. Redfern, M.D.—*Dep. of Zool. and Bot.*, Dr. Hooker, C.B., Pres.R.S.—*Dep. of Anthrop.*, Sir W.R.Wilde, M.D.	W. T. Thiselton-Dyer, R. O. Cunningham, Dr. J. J. Charles, Dr. P. H. Pye-Smith, J. J. Murphy, F. W. Rudler.
1875. Bristol	P. L. Sclater, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Cleland, F.R.S.—*Dep. of Anth.*, Prof. Rolleston, F.R.S.	E. R. Alston, Dr. McKendrick, Prof. W. R. M'Nab, Dr. Martyn, F. W. Rudler, Dr. P. H. Pye-Smith, Dr. W. Spencer.
1876. Glasgow	A. Russel Wallace, F.L.S.—*Dep. of Zool. and Bot.*, Prof. A. Newton, F.R.S.—*Dep. of Anat. and Physiol.*, Dr. J. G. McKendrick.	E. R. Alston, Hyde Clarke, Dr. Knox, Prof. W. R. M'Nab, Dr. Muirhead, Prof. Morrison Watson.
1877. Plymouth...	J. Gwyn Jeffreys, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Macalister.—*Dep. of Anthropol.*, F. Galton, F.R.S.	E. R. Alston, F. Brent, Dr. D. J. Cunningham, Dr. C. A. Hingston, Prof. W. R. M'Nab, J. B. Rowe, F. W. Rudler.
1878. Dublin	Prof. W. H. Flower, F.R.S.—*Dep. of Anthropol.*, Prof. Huxley, Sec. R.S.—*Dep. of Anat. and Physiol.*, R. McDonnell, M.D., F.R.S.	Dr. R. J. Harvey, Dr. T. Hayden, Prof. W. R. M'Nab, Prof. J. M. Purser, J. B. Rowe, F. W. Rudler.
1879. Sheffield ...	Prof. St. George Mivart, F.R.S.—*Dep. of Anthropol.*, E. B. Tylor, D.C.L., F.R.S.—*Dep. of Anat. and Physiol.*, Dr. Pye-Smith.	Arthur Jackson, Prof. W. R. M'Nab, J. B. Rowe, F. W. Rudler, Prof. Schäfer.
1880. Swansea ...	A.C. L. Günther, F.R.S.—*Dep. of Anat. & Physiol.*, F. M. Balfour, F.R.S.—*Dep. of Anthropol.*, F. W. Rudler.	G. W. Bloxam, John Priestley, Howard Saunders, Adam Sedgwick.
1881. York........	R. Owen, F.R.S.—*Dep. of Anthropol.*, Prof. W. H. Flower, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. J. S. Burdon Sanderson, F.R.S.	G. W. Bloxam, W. A. Forbes, Rev. W. C. Hey, Prof. W. R. M'Nab, W. North, John Priestley, Howard Saunders, H. E. Spencer.
1882. Southampton.	Prof. A. Gamgee, M.D., F.R.S.—*Dep. of Zool. and Bot.*, Prof. M. A. Lawson, F.L.S.—*Dep. of Anthropol.*, Prof. W. Boyd Dawkins, F.R.S.	G. W. Bloxam, W. Heape, J. B. Nias, Howard Saunders, A. Sedgwick, T. W. Shore, jun.
1883. Southport[1]	Prof. E. Ray Lankester, M.A., F.R.S.—*Dep. of Anthropol.*, W. Pengelly, F.R.S.	G. W. Bloxam, Dr. G. J. Haslam, W. Heape, W. Hurst, Prof. A. M. Marshall, Howard Saunders, Dr. G. A. Woods.
1884. Montreal ...	Prof. H. N. Moseley, M.A., F.R.S.	Prof. W. Osler, Howard Saunders, A. Sedgwick, Prof. R. R. Wright.
1885. Aberdeen...	Prof. W. C. M'Intosh, M.D., LL.D., F.R.S., F.R.S.E.	W. Heape, J. McGregor-Robertson, J. Duncan Matthews, Howard Saunders, H. Marshall Ward.
1886. Birmingham	W. Carruthers, Pres. L.S., F.R.S., F.G.S.	Prof. T. W. Bridge, W. Heape, Prof. W. Hillhouse, W. L. Sclater, Prof. H. Marshall Ward.
1887. Manchester	Prof. A. Newton, M.A., F.R.S., F.L.S., V.P.Z.S.	C. Bailey, F. E. Beddard, S. F. Harmer, W. Heape, W. L. Sclater, Prof. H. Marshall Ward.

[1] Anthropology was made a separate Section, see p. lxxi.

Date and Place	Presidents	Secretaries
1888. Bath.........	W. T. Thiselton-Dyer, C.M.G., F.R.S., F.L.S.	F. E. Beddard, S. F. Harmer, Prof. H. Marshall Ward, W. Gardiner, Prof. W. D. Halliburton.
1889. Newcastle-upon-Tyne	Prof. J. S. Burdon Sanderson, M.A., M.D., F.R.S.	C. Bailey, F. E. Beddard, S. F. Harmer, Prof. T. Oliver, Prof. H. Marshall Ward.
1890. Leeds	Prof. A. Milnes Marshall, M.A., M.D., D.Sc., F.R.S.	S. F. Harmer, Prof. W. A. Herdman, S. J. Hickson, F. W. Oliver, H. Wager, H. Marshall Ward.
1891. Cardiff......	Francis Darwin, M.A., M.B., F.R.S., F.L.S.	F. E. Beddard, Prof. W. A. Herdman, Dr. S. J. Hickson, G. Murray, Prof. W. N. Parker, H. Wager.
1892. Edinburgh	Prof. W. Rutherford, M.D., F.R.S., F.R.S.E.	G. Brook, Prof. W. A. Herdman, G. Murray, W. Stirling, H. Wager.
1893. Nottingham[1]	Rev. Canon H. B. Tristram, M.A., LL.D., F.R.S.	G. C. Bourne, J. B. Farmer, Prof. W. A. Herdman, S. J. Hickson, W. B. Ransom, W. L. Sclater.
1894. Oxford[2] ...	Prof. I. Bayley Balfour, M.A., F.R.S.	W. W. Benham, Prof. J. B. Farmer, Prof. W. A. Herdman, Prof. S. J. Hickson, G. Murray, W. L. Sclater.

SECTION D (*continued*).—ZOOLOGY.

1895. Ipswich ...	Prof. W. A. Herdman, F.R.S.	G. C. Bourne, H. Brown, W. E. Hoyle, W. L. Sclater.
1896. Liverpool...	Prof. E. B. Poulton, F.R.S. ...	H. O. Forbes, W. Garstang, W. E. Hoyle.
1897. Toronto ...	Prof. L. C. Miall, F.R.S.	W. Garstang, W. E. Hoyle, Prof. E. E. Prince.
1898. Bristol......	Prof. W. F. R. Weldon, F.R.S.	Prof. R. Boyce, W. Garstang, Dr. A. J. Harrison, W. E. Hoyle.
1899. Dover	Adam Sedgwick, F.R.S.	W. Garstang, J. Graham Kerr.
1900. Bradford ...	Dr. R. H. Traquair, F.R.S. ...	W. Garstang, J. G. Kerr, T. H. Taylor, Swale Vincent.
1901. Glasgow ...	Prof. J. Cossar Ewart, F.R.S.	J. G. Kerr, J. Rankin, J. Y. Simpson.

ANATOMICAL AND PHYSIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, V.—ANATOMY AND PHYSIOLOGY.

1833. Cambridge	Dr. J. Haviland...	Dr. H. J. H. Bond, Mr. G. E. Paget.
1834. Edinburgh	Dr. Abercrombie	Dr. Roget, Dr. William Thomson.

SECTION E (UNTIL 1847).—ANATOMY AND MEDICINE.

1835. Dublin	Dr. J. C. Pritchard	Dr. Harrison, Dr. Hart.
1836. Bristol	Dr. P. M. Roget, F.R.S.	Dr. Symonds.
1837. Liverpool.	Prof. W. Clark, M.D.	Dr. J. Carson, jun., James Long, Dr. J. R. W. Vose.
1838. Newcastle	T. E. Headlam, M.D.	T. M. Greenhow, Dr. J. R. W. Vose.
1839. Birmingham	John Yelloly, M.D., F.R.S....	Dr. G. O. Rees, F. Ryland.
1840. Glasgow ...	James Watson, M.D.	Dr. J. Brown, Prof. Couper, Prof. Reid.

SECTION E.—PHYSIOLOGY.

1841. Plymouth...	P. M. Roget, M.D., Sec. R.S.	J. Butter, J. Fuge, R. S. Sargent.
1842. Manchester	Edward Holme, M.D., F.L.S.	Dr. Chaytor, Dr. R. S. Sargent.
1843. Cork	Sir James Pitcairn, M.D. ...	Dr. John Popham, Dr. R. S. Sargent.
1844. York	J. C. Pritchard, M.D.	I. Erichsen, Dr. R. S. Sargent.
1845. Cambridge	Prof. J. Haviland, M.D.	Dr. R. S. Sargent, Dr. Webster.

[1] Physiology was made a separate Section, see p. lxxii.
[2] The title of Section D was changed to Zoology.

Date and Place	Presidents	Secretaries
1846. Southampton.	Prof. Owen, M.D., F.R.S. ...	C. P. Keele, Dr. Laycock, Dr. Sargent.
1847. Oxford [1] ...	Prof. Ogle, M.D., F.R.S.	T. K. Chambers, W. P. Ormerod.

PHYSIOLOGICAL SUBSECTIONS OF SECTION D.

1850. Edinburgh	Prof. Bennett, M.D., F.R.S.E.	
1855. Glasgow ...	Prof. Allen Thomson, F.R.S.	Prof. J. H. Corbett, Dr. J. Struthers.
1857. Dublin......	Prof. R. Harrison, M.D.	Dr. R. D. Lyons, Prof. Redfern.
1858. Leeds	Sir B. Brodie, Bart., F.R.S.	C. G. Wheelhouse.
1859. Aberdeen...	Prof. Sharpey, M.D., Sec.R.S.	Prof. Bennett, Prof. Redfern.
1860. Oxford......	Prof.G.Rolleston,M.D.,F.L.S.	Dr. R. M'Donnell, Dr. Edward Smith.
1861. Manchester	Dr. John Davy, F.R.S. L.& E.	Dr. W. Roberts, Dr. Edward Smith.
1862. Cambridge	G. E. Paget, M.D................	G. F. Helm, Dr. Edward Smith.
1863. Newcastle	Prof. Rolleston, M.D., F.R.S.	Dr. D. Embleton, Dr. W. Turner.
1864. Bath.........	Dr. Edward Smith, F.R.S.	J. S. Bartrum, Dr. W. Turner.
1865. Birmingham [2]	Prof. Acland, M.D., LL.D., F.R.S.	Dr. A. Fleming, Dr. P. Heslop, Oliver Pembleton, Dr. W. Turner.

GEOGRAPHICAL AND ETHNOLOGICAL SCIENCES.

[For Presidents and Secretaries for Geography previous to 1851, see Section C, p. lviii.]

ETHNOLOGICAL SUBSECTIONS OF SECTION D.

1846. Southampton	Dr. J. C. Pritchard	Dr. King.
1847. Oxford	Prof. H. H. Wilson, M.A.	Prof. Buckley.
1848. Swansea ...		G. Grant Francis.
1849. Birmingham		Dr. R. G. Latham.
1850. Edinburgh	Vice-Admiral Sir A. Malcolm	Daniel Wilson.

SECTION E.—GEOGRAPHY AND ETHNOLOGY.

1851. Ipswich ...	Sir R. I. Murchison, F.R.S., Pres. R.G.S.	R. Cull, Rev. J. W. Donaldson, Dr. Norton Shaw.
1852. Belfast......	Col. Chesney, R.A., D.C.L., F.R.S.	R. Cull, R. MacAdam, Dr. Norton Shaw.
1853. Hull.	R. G. Latham, M.D., F.R.S.	R. Cull, Rev. H. W. Kemp, Dr. Norton Shaw.
1854. Liverpool...	Sir R. I. Murchison, D.C.L., F.R.S.	Richard Cull, Rev. H. Higgins, Dr. Ihne, Dr. Norton Shaw.
1855. Glasgow ...	Sir J. Richardson, M.D., F.R.S.	Dr. W. G. Blackie, R. Cull, Dr. Norton Shaw.
1856. Cheltenham	Col. Sir H. C. Rawlinson, K.C.B.	R. Cull, F. D. Hartland, W. H. Rumsey, Dr. Norton Shaw.
1857. Dublin......	Rev. Dr. J. Henthorn Todd, Pres. R.I.A.	R. Cull, S. Ferguson, Dr. R. R. Madden, Dr. Norton Shaw.
1858. Leeds	Sir R. I. Murchison, G.C.St.S., F.R.S.	R. Cull, F. Galton, P. O'Callaghan, Dr. Norton Shaw, T. Wright.

[1] Sections D and E were incorporated under the name of 'Section D—Zoology and Botany, including Physiology' (see p. lxi.). Section E, being then vacant, was assigned in 1851 to Geography.

[2] *Vide* note on page lxii.

Date and Place	Presidents	Secretaries
1859. Aberdeen...	Rear - Admiral Sir James Clerk Ross, D.C.L., F.R.S.	Richard Cull, Prof. Geddes, Dr. Norton Shaw.
1860. Oxford......	Sir R. I. Murchison, D.C.L., F.R.S.	Capt. Burrows, Dr. J. Hunt, Dr. C. Lemprière, Dr. Norton Shaw.
1861. Manchester	John Crawfurd, F.R.S..........	Dr. J. Hunt, J. Kingsley, Dr. Norton Shaw, W. Spottiswoode.
1862. Cambridge	Francis Galton, F.R.S..........	J. W. Clarke, Rev. J. Glover, Dr. Hunt, Dr. Norton Shaw, T. Wright.
1863. Newcastle	Sir R. I. Murchison, K.C.B., F.R.S.	C. Carter Blake, Hume Greenfield, C. R. Markham, R. S. Watson.
1864. Bath.........	Sir R. I. Murchison, K.C.B., F.R.S.	H. W. Bates, C. R. Markham, Capt. R. M. Murchison, T. Wright.
1865. Birmingham	Major-General Sir H. Rawlinson, M.P., K.C.B., F.R.S.	H. W. Bates, S. Evans, G. Jabet, C. R. Markham, Thomas Wright.
1866. Nottingham	Sir Charles Nicholson, Bart., LL.D.	H. W. Bates, Rev. E. T. Cusins, R. H. Major, Clements R. Markham, D. W. Nash, T. Wright.
1867. Dundee ...	Sir Samuel Baker, F.R.G.S.	H. W. Bates, Cyril Graham, C. R. Markham, S. J. Mackie, R. Sturrock.
1868. Norwich ...	Capt. G. H. Richards, R.N., F.R.S.	T. Baines, H. W. Bates, Clements R. Markham, T. Wright.

SECTION E (*continued*).—GEOGRAPHY.

1869. Exeter......	Sir Bartle Frere, K.C.B., LL.D., F.R.G.S.	H. W. Bates, Clements R. Markham, J. H. Thomas.
1870. Liverpool...	Sir R. I. Murchison, Bt., K.C.B., LL.D., D.C.L., F.R.S., F.G.S.	H. W. Bates, David Buxton, Albert J. Mott, Clements R. Markham.
1871. Edinburgh	Colonel Yule, C.B., F.R.G.S.	A. Buchan, A. Keith Johnston, Clements R. Markham, J. H. Thomas.
1872. Brighton .	Francis Galton, F.R.S..........	H. W. Bates, A. Keith Johnston, Rev. J. Newton, J. H. Thomas.
1873. Bradford .	Sir Rutherford Alcock, K.C.B.	H. W. Bates, A. Keith Johnston, Clements R. Markham.
1874. Belfast....	Major Wilson, R.E., F.R.S., F.R.G.S.	E. G. Ravenstein, E. C. Rye, J. H. Thomas.
1875. Bristol....	Lieut. - General Strachey, R.E., C.S.I., F.R.S., F.R.G.S.	H. W. Bates, E. C. Rye, F. F. Tuckett.
1876. Glasgow .	Capt. Evans, C.B., F.R.S.......	H. W. Bates, E. C. Rye, R. O. Wood.
1877. Plymouth..	Adm. Sir E. Ommanney, C.B.	H. W. Bates, F. E. Fox, E. C. Rye.
1878. Dublin......	Prof. Sir C. Wyville Thomson, LL.D., F.R.S., F.R.S.E.	John Coles, E. C. Rye.
1879. Sheffield ...	Clements R. Markham, C.B., F.R.S., Sec. R.G.S.	H. W. Bates, C. E. D. Black, E. C. Rye.
1880. Swansea ...	Lieut.-Gen. Sir J. H. Lefroy, C.B., K.C.M.G., R.A., F.R.S.	H. W. Bates, E. C. Rye.
1881. York.........	Sir J. D. Hooker, K.C.S.I., C.B., F.R.S.	J. W. Barry, H. W. Bates.
1882. Southampton.	Sir R. Temple, Bart., G.C.S.I., F.R.G.S.	E. G. Ravenstein, E. C. Rye.
1883. Southport	Lieut.-Col. H. H. Godwin-Austen, F.R.S.	John Coles, E. G. Ravenstein, E. C. Rye.
1884. Montreal ...	Gen. Sir J. H. Lefroy, C.B., K.C.M.G., F.R.S., V.P.R.G.S.	Rev. Abbé Laflamme, J. S. O'Halloran, E. G. Ravenstein, J. F. Torrance.
1885. Aberdeen...	Gen. J. T. Walker, C.B., R.E., LL.D., F.R.S.	J. S. Keltie, J. S. O'Halloran, E. G. Ravenstein, Rev. G. A. Smith.
1886. Birmingham	Maj.-Gen. Sir. F. J. Goldsmid, K.C.S.I., C.B., F.R.G.S.	F. T. S. Houghton, J. S. Keltie, E. G. Ravenstein.
1887. Manchester	Col. Sir C. Warren, R.E., G.C.M.G., F.R.S., F.R.G.S.	Rev. L. C. Casartelli, J. S. Keltie, H. J. Mackinder, E. G. Ravenstein.

Date and Place	Presidents	Secretaries
1888. Bath	Col. Sir C. W. Wilson, R.E., K.C.B., F.R.S., F.R.G.S.	J. S. Keltie, H. J. Mackinder, E. G. Ravenstein.
1889. Newcastle-upon-Tyne	Col. Sir F. de Winton, K.C.M.G., C.B., F.R.G.S.	J. S. Keltie, H. J. Mackinder, R. Sulivan, A. Silva White.
1890. Leeds	Lieut.-Col. Sir R. Lambert Playfair, K.C.M.G., F.R.G.S.	A. Barker, John Coles, J. S. Keltie, A. Silva White.
1891. Cardiff	E. G. Ravenstein, F.R.G.S., F.S.S.	John Coles, J. S. Keltie, H. J. Mackinder, A. Silva White, Dr. Yeats.
1892. Edinburgh	Prof. J. Geikie, D.C.L., F.R.S., V.P.R.Scot.G.S.	J. G. Bartholomew, John Coles, J. S. Keltie, A. Silva White.
1893. Nottingham	H. Seebohm, Sec. R.S., F.L.S., F.Z.S.	Col. F. Bailey, John Coles, H. O. Forbes, Dr. H. R. Mill.
1894. Oxford	Capt. W. J. L. Wharton, R.N., F.R.S.	John Coles, W. S. Dalgleish, H. N. Dickson, Dr. H. R. Mill.
1895. Ipswich	H. J. Mackinder, M.A., F.R.G.S.	John Coles, H. N. Dickson, Dr. H. R. Mill, W. A. Taylor.
1896. Liverpool	Major L. Darwin, Sec. R.G.S.	Col. F. Bailey, H. N. Dickson, Dr. H. R. Mill, E. C. DuB. Phillips.
1897. Toronto	J. Scott-Keltie, LL.D.	Col. F. Bailey, Capt. Deville, Dr. H. R. Mill, J. B. Tyrrell.
1898. Bristol	Col. G. Earl Church, F.R.G.S.	H. N. Dickson, Dr. H. R. Mill, H. C. Trapnell.
1899. Dover	Sir John Murray, F.R.S.	H. N. Dickson, Dr. H. O. Forbes, Dr. H. R. Mill.
1900. Bradford	Sir George S. Robertson, K.C.S.I.	H. N. Dickson, E. Heawood, E. R. Wethey.
1901. Glasgow	Dr. H. R. Mill, F.R.G.S.	H. N. Dickson, E. Heawood, G. Sandeman, A. C. Turner.

STATISTICAL SCIENCE.

COMMITTEE OF SCIENCES, VI.—STATISTICS.

1833. Cambridge	Prof. Babbage, F.R.S.	J. E. Drinkwater.
1834. Edinburgh	Sir Charles Lemon, Bart.	Dr. Cleland, C. Hope Maclean.

SECTION F.—STATISTICS.

1835. Dublin	Charles Babbage, F.R.S.	W. Greg, Prof. Longfield.
1836. Bristol	Sir Chas. Lemon, Bart., F.R.S.	Rev. J. E. Bromby, C. B. Fripp, James Heywood.
1837. Liverpool	Rt. Hon. Lord Sandon	W. R. Greg, W. Langton, Dr. W. C. Tayler.
1838. Newcastle	Colonel Sykes, F.R.S.	W. Cargill, J. Heywood, W. R. Wood.
1839. Birmingham	Henry Hallam, F.R.S.	F. Clarke, R. W. Rawson, Dr. W. C. Tayler.
1840. Glasgow	Lord Sandon, M.P., F.R.S.	C. R. Baird, Prof. Ramsay, R. W. Rawson.
1841. Plymouth	Lieut.-Col. Sykes, F.R.S.	Rev. Dr. Byrth, Rev. R. Luney, R. W. Rawson.
1842. Manchester	G. W. Wood, M.P., F.L.S.	Rev. R. Luney, G. W. Ormerod, Dr. W. C. Tayler.
1843. Cork	Sir C. Lemon, Bart., M.P.	Dr. D. Bullen, Dr. W. Cooke Tayler.
1844. York	Lieut.-Col. Sykes, F.R.S., F.L.S.	J. Fletcher, J. Heywood, Dr. Laycock.
1845. Cambridge	Rt. Hon. the Earl Fitzwilliam	J. Fletcher, Dr. W. Cooke Tayler.
1846. Southampton.	G. R. Porter, F.R.S.	J. Fletcher, F. G. P. Neison, Dr. W. C. Tayler, Rev. T. L. Shapcott.
1847. Oxford	Travers Twiss, D.C.L., F.R.S.	Rev. W. H. Cox, J. J. Danson, F. G. P. Neison.
1848. Swansea	J. H. Vivian, M.P., F.R.S.	J. Fletcher, Capt. R. Shortrede.
1849. Birmingham	Rt. Hon. Lord Lyttelton	Dr. Finch, Prof. Hancock, F. P. G. Neison.

Date and Place	Presidents	Secretaries
1850. Edinburgh	Very Rev. Dr. John Lee, V.P.R.S.E.	Prof. Hancock, J. Fletcher, Dr. J. Stark.
1851. Ipswich ...	Sir John P. Boileau, Bart. ...	J. Fletcher, Prof. Hancock.
1852. Belfast......	His Grace the Archbishop of Dublin.	Prof. Hancock, Prof. Ingram, James MacAdam, jun.
1853. Hull.........	James Heywood, M.P., F.R.S.	Edward Cheshire, W. Newmarch.
1854. Liverpool...	Thomas Tooke, F.R.S.	E. Cheshire, J. T. Danson, Dr. W. H. Duncan, W. Newmarch.
1855. Glasgow ...	R. Monckton Milnes, M.P. ...	J. A. Campbell, E. Cheshire, W. Newmarch, Prof. R. H. Walsh.
SECTION F (*continued*).—ECONOMIC SCIENCE AND STATISTICS.		
1856. Cheltenham	Rt. Hon. Lord Stanley, M.P.	Rev. C. H. Bromby, E. Cheshire, Dr. W. N. Hancock, W. Newmarch, W. M. Tartt.
1857. Dublin.	His Grace the Archbishop of Dublin, M.R.I.A.	Prof. Cairns, Dr. H. D. Hutton, W. Newmarch.
1858. Leeds	Edward Baines	T. B. Baines, Prof. Cairns, S. Brown, Capt. Fishbourne, Dr. J. Strang.
1859. Aberdeen...	Col. Sykes, M.P., F.R.S.	Prof. Cairns, Edmund Macrory, A. M. Smith, Dr. John Strang.
1860. Oxford	Nassau W. Senior, M.A.	Edmund Macrory, W. Newmarch, Prof. J. E. T. Rogers.
1861. Manchester	William Newmarch, F.R.S....	David Chadwick, Prof. R. C. Christie, E. Macrory, Prof. J. E. T. Rogers.
1862. Cambridge	Edwin Chadwick, C.B.	H. D. Macleod, Edmund Macrory.
1863. Newcastle .	William Tite, M.P., F.R.S. ...	T. Doubleday, Edmund Macrory, Frederick Purdy, James Potts.
1864. Bath.........	W. Farr, M.D., D.C.L., F.R.S.	E. Macrory, E. T. Payne, F. Purdy.
1865. Birmingham	Rt. Hon. Lord Stanley, LL.D., M.P.	G. J. D. Goodman, G. J. Johnston, E. Macrory.
1866. Nottingham	Prof. J. E. T. Rogers............	R. Birkin, jun., Prof. Leone Levi, E. Macrory.
1867. Dundee	M. E. Grant-Duff, M.P.	Prof. Leone Levi, E. Macrory, A. J. Warden.
1868. Norwich	Samuel Brown	Rev. W. C. Davie, Prof. Leone Levi.
1869. Exeter	Rt. Hon. Sir Stafford H. Northcote, Bart., C.B., M.P.	E. Macrory, F. Purdy, C. T. D. Acland.
1870. Liverpool...	Prof. W. Stanley Jevons, M.A.	Chas. R. Dudley Baxter, E. Macrory, J. Miles Moss.
1871. Edinburgh .	Rt. Hon. Lord Neaves	J. G. Fitch, James Meikle.
1872. Brighton ...	Prof. Henry Fawcett, M.P....	J. G. Fitch, Barclay Phillips.
1873. Bradford ...	Rt. Hon. W. E. Forster, M.P.	J. G. Fitch, Swire Smith.
1874. Belfast......	Lord O'Hagan	Prof. Donnell, F. P. Fellows, Hans MacMordie.
1875. Bristol	James Heywood, M.A., F.R.S., Pres. S.S.	F. P. Fellows, T. G. P. Hallett, E. Macrory.
1876. Glasgow ...	Sir George Campbell, K.C.S.I., M.P.	A. M'Neel Caird, T. G. P. Hallett, Dr. W. Neilson Hancock, Dr. W. Jack.
1877. Plymouth...	Rt. Hon. the Earl Fortescue	W. F. Collier, P. Hallett, J. T. Pim.
1878. Dublin	Prof. J. K. Ingram, LL.D.	W. J. Hancock, C. Molloy, J. T. Pim.
1879. Sheffield ...	G. Shaw Lefevre, M.P., Pres. S.S.	Prof. Adamson, R. E. Leader, C. Molloy.
1880. Swansea ...	G. W. Hastings, M.P.	N. A. Humphreys, C. Molloy.
1881. York........	Rt. Hon. M. E. Grant-Duff, M.A., F.R.S.	C. Molloy, W. W. Morrell, J. F. Moss.
1882. Southampton.	Rt. Hon. G. Sclater-Booth, M.P., F.R.S.	G. Baden-Powell, Prof. H. S. Foxwell, A. Milnes, C. Molloy.
1883. Southport	R. H. Inglis Palgrave, F.R.S.	Rev. W. Cunningham, Prof. H. S. Foxwell, J. N. Keynes, C. Molloy

Date and Place	Presidents	Secretaries
1884. Montreal ...	Sir Richard Temple, Bart., G.C.S.I., C.I.E., F.R.G.S.	Prof. H. S. Foxwell, J. S. McLennan, Prof. J. Watson.
1885. Aberdeen...	Prof. H. Sidgwick, LL.D., Litt.D.	Rev. W. Cunningham, Prof. H. S. Foxwell, C. McCombie, J. F. Moss.
1886. Birmingham	J. B. Martin, M.A., F.S.S.	F. F. Barham, Rev. W. Cunningham, Prof. H. S. Foxwell, J. F. Moss.
1887. Manchester	Robert Giffen, LL.D., V.P.S.S.	Rev. W. Cunningham, F. Y. Edgeworth, T. H. Elliott, C. Hughes, J. E. C. Munro, G. H. Sargant.
1888. Bath.........	Rt. Hon. Lord Bramwell, LL.D., F.R.S.	Prof. F. Y. Edgeworth, T. H. Elliott, H. S. Foxwell, L. L. F. R. Price.
1889. Newcastle-upon-Tyne	Prof. F. Y. Edgeworth, M.A., F.S.S.	Rev. Dr. Cunningham, T. H. Elliott, F. B. Jevons, L. L. F. R. Price.
1890. Leeds	Prof. A. Marshall, M.A., F.S.S.	W. A. Brigg, Rev. Dr. Cunningham, T. H. Elliott, Prof. J. E. C. Munro, L. L. F. R. Price.
1891. Cardiff......	Prof. W. Cunningham, D.D., D.Sc., F.S.S.	Prof. J. Brough, E. Cannan, Prof. E. C. K. Gonner, H. Ll. Smith, Prof. W. R. Sorley.
1892. Edinburgh	Hon. Sir C. W. Fremantle, K.C.B.	Prof. J. Brough, J. R. Findlay, Prof. E. C. K. Gonner, H. Higgs, L. L. F. R. Price.
1893. Nottingham	Prof. J. S. Nicholson, D.Sc., F.S.S.	Prof. E. C. K. Gonner, H. de B. Gibbins, J. A. H. Green, H. Higgs, L. L. F. R. Price.
1894. Oxford......	Prof. C. F. Bastable, M.A., F.S.S.	E. Cannan, Prof. E. C. K. Gonner W. A. S. Hewins, H. Higgs.
1895. Ipswich ...	L. L. Price, M.A.	E. Cannan, Prof. E. C. K. Gonner, H. Higgs.
1896. Liverpool...	Rt. Hon. L. Courtney, M.P....	E. Cannan, Prof. E. C. K. Gonner, W. A. S. Hewins, H. Higgs.
1897. Toronto ...	Prof. E. C. K. Gonner, M.A.	E. Cannan, H. Higgs, Prof. A. Shortt.
1898. Bristol... ..	J. Bonar, M.A., LL.D.	E. Cannan, Prof. A. W. Flux, H. Higgs, W. E. Tanner.
1899. Dover	H. Higgs, LL.B.	A. L. Bowley, E. Cannan, Prof. A. W. Flux, Rev. G. Sarson.
1900. Bradford ...	Major P. G. Craigie, V.P.S.S.	A. L. Bowley, E. Cannan, S. J. Chapman, F. Hooper.
1901. Glasgow ...	Sir R. Giffen, K.C.B., F.R.S.	W. W. Blackie, A. L. Bowley, E. Cannan, S. J. Chapman.

SECTION G.—MECHANICAL SCIENCE.

1836. Bristol......	Davies Gilbert, D.C.L., F.R.S.	T. G. Bunt, G. T. Clark, W. West.
1837. Liverpool...	Rev. Dr. Robinson	Charles Vignoles, Thomas Webster.
1838. Newcastle	Charles Babbage, F.R.S.......	R. Hawthorn, C. Vignoles, T. Webster.
1839. Birmingham	Prof. Willis, F.R.S., and Robt. Stephenson.	W. Carpmael, William Hawkes, T. Webster.
1840. Glasgow	Sir John Robinson	J. Scott Russell, J. Thomson, J. Tod, C. Vignoles.
1841. Plymouth	John Taylor, F.R.S.	Henry Chatfield, Thomas Webster.
1842. Manchester	Rev. Prof. Willis, F.R.S.	J. F. Bateman, J. Scott Russell, J. Thomson, Charles Vignoles.
1843. Cork	Prof. J. Macneill, M.R.I.A....	James Thomson, Robert Mallet.
1844. York.........	John Taylor, F.R.S.	Charles Vignoles, Thomas Webster.
1845. Cambridge	George Rennie, F.R.S..........	Rev. W. T. Kingsley.
1846. South'mpt'n	Rev. Prof. Willis, M.A., F.R.S.	William Betts, jun., Charles Manby.
1847. Oxford......	Rev. Prof. Walker, M.A., F.R.S.	J. Glynn, R. A. Le Mesurier.
1848. Swansea ...	Rev. Prof. Walker, M.A., F.R.S.	R. A. Le Mesurier, W. P. Struvé.
1849. Birmingham	Robt. Stephenson, M.P., F.R.S.	Charles Manby, W. P. Marshall.
1850. Edinburgh	Rev. R. Robinson	Dr. Lees, David Stephenson.

Date and Place	Presidents	Secretaries
1851. Ipswich ...	William Cubitt, F.R.S.	John Head, Charles Manby.
1852. Belfast......	John Walker, C.E., LL.D., F.R.S.	John F. Bateman, C. B. Hancock, Charles Manby, James Thomson.
1853. Hull	William Fairbairn, F.R.S.	J. Oldham, J. Thomson, W. S. Ward.
1854. Liverpool...	John Scott Russell, F.R.S. ...	J. Grantham, J. Oldham, J. Thomson.
1855. Glasgow ...	W. J. M. Rankine, F.R.S. ...	L. Hill, W. Ramsay, J. Thomson.
1856. Cheltenham	George Rennie, F.R.S.	C. Atherton, B. Jones, H. M. Jeffery.
1857. Dublin......	Rt. Hon. the Earl of Rosse, F.R.S.	Prof. Downing, W.T. Doyne, A. Tate, James Thomson, Henry Wright.
1858. Leeds	William Fairbairn, F.R.S. ...	J. C. Dennis, J. Dixon, H. Wright.
1859. Aberdeen...	Rev. Prof. Willis, M.A., F.R.S.	R. Abernethy, P. Le Neve Foster, H. Wright.
1860. Oxford	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, Rev. F. Harrison, Henry Wright.
1861. Manchester	J. F. Bateman, C.E., F.R.S....	P. Le Neve Foster, John Robinson, H. Wright.
1862. Cambridge.	William Fairbairn, F.R.S.	W. M. Fawcett, P. Le Neve Foster.
1863. Newcastle .	Rev. Prof. Willis, M.A., F.R.S.	P. Le Neve Foster, P. Westmacott, J. F. Spencer.
1864. Bath	J. Hawkshaw, F.R.S.	P. Le Neve Foster, Robert Pitt.
1865. Birmingham	Sir W. G. Armstrong, LL.D., F.R.S.	P. Le Neve Foster, Henry Lea, W. P. Marshall, Walter May.
1866. Nottingham	Thomas Hawksley, V.P. Inst. C.E., F.G.S.	P. Le Neve Foster, J. F. Iselin, M. O. Tarbotton.
1867. Dundee......	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, John P. Smith, W. W. Urquhart.
1868. Norwich ...	G. P. Bidder, C.E., F.R.G.S.	P. Le Neve Foster, J. F. Iselin, C. Manby, W. Smith.
1869. Exeter	C. W. Siemens, F.R.S.	P. Le Neve Foster, H. Bauerman.
1870. Liverpool...	Chas. B. Vignoles, C.E., F.R.S.	H. Bauerman, P. Le Neve Foster, T. King, J. N. Shoolbred.
1871. Edinburgh	Prof. Fleeming Jenkin, F.R.S.	H. Bauerman, A. Leslie, J. P. Smith.
1872. Brighton ...	F. J. Bramwell, C.E.	H. M. Brunel, P. Le Neve Foster, J. G. Gamble, J. N. Shoolbred.
1873. Bradford ...	W. H. Barlow, F.R.S.	C. Barlow, H. Bauerman, E. H. Carbutt, J. C. Hawkshaw, J. N. Shoolbred.
1874. Belfast	Prof. James Thomson, LL.D., C.E., F.R.S.E.	A. T. Atchison, J. N. Shoolbred, John Smyth, jun.
1875. Bristol	W. Froude, C.E., M.A., F.R.S.	W. R. Browne, H. M. Brunel, J. G. Gamble, J. N. Shoolbred.
1876. Glasgow ...	C. W. Merrifield, F.R.S.	W. Bottomley, jun., W. J. Millar, J. N. Shoolbred, J. P. Smith.
1877. Plymouth...	Edward Woods, C.E.	A. T. Atchison, Dr. Merrifield, J. N. Shoolbred.
1878. Dublin	Edward Easton, C.E.	A. T. Atchison, R. G. Symes, H. T. Wood.
1879. Sheffield ...	J. Robinson, Pres. Inst. Mech. Eng.	A. T. Atchison, Emerson Bainbridge, H. T. Wood.
1880. Swansea ...	J. Abernethy, F.R.S.E.	A. T. Atchison, H. T. Wood.
1881. York.........	Sir W. G. Armstrong, C.B., LL.D., D.C.L., F.R.S.	A. T. Atchison, J. F. Stephenson, H. T. Wood.
1882. Southampton.	John Fowler, C.E., F.G.S. ...	A. T. Atchison, F. Churton, H. T. Wood.
1883. Southport .	J. Brunlees, Pres. Inst. C.E.	A. T. Atchison, E. Rigg, H. T. Wood.
1884. Montreal ...	Sir F. J. Bramwell, F.R.S., V.P. Inst. C.E.	A. T. Atchison, W. B. Dawson, J. Kennedy, H. T. Wood.
1885. Aberdeen...	B. Baker, M. Inst. C.E.	A. T. Atchison, F. G. Ogilvie, E. Rigg, J. N. Shoolbred.
1886. Birmingham	Sir J. N. Douglass, M. Inst. C.E.	C. W. Cooke, J. Kenward, W. B. Marshall, E. Rigg.

Date and Place	Presidents	Secretaries
1887. Manchester	Prof. Osborne Reynolds, M.A., LL.D., F.R.S.	C. F. Budenberg, W. B. Marshall, E. Rigg.
1888. Bath.........	W. H. Preece, F.R.S., M.Inst.C.E.	C. W. Cooke, W. B. Marshall, E. Rigg, P. K. Stothert.
1889. Newcastle-upon-Tyne	W. Anderson, M.Inst.C.E. ...	C. W. Cooke, W. B. Marshall, Hon. C. A. Parsons, E. Rigg.
1890. Leeds	Capt. A. Noble, C.B., F.R.S., F.R.A.S.	E. K. Clark, C. W. Cooke, W. B. Marshall, E. Rigg.
1891. Cardiff......	T. Forster Brown, M.Inst.C.E.	C. W. Cooke, Prof. A. C. Elliott, W. B. Marshall, E. Rigg.
1892. Edinburgh	Prof. W. C. Unwin, F.R.S., M.Inst.C.E.	C. W. Cooke, W. B. Marshall, W. C. Popplewell, E. Rigg.
1893. Nottingham	Jeremiah Head, M.Inst.C.E., F.C.S.	C. W. Cooke, W. B. Marshall, E. Rigg, H. Talbot.
1894. Oxford......	Prof. A. B. W. Kennedy, F.R.S., M.Inst.C.E.	Prof. T. Hudson Beare, C. W. Cooke, W. B. Marshall, Rev. F. J. Smith.
1895. Ipswich ...	Prof. L. F. Vernon-Harcourt, M.A., M.Inst.C.E.	Prof. T. Hudson Beare, C. W. Cooke, W. B. Marshall, P. G. M. Stoney.
1896. Liverpool...	Sir Douglas Fox, V.P.Inst.C.E.	Prof. T. Hudson Beare, C. W. Cooke, S. Dunkerley, W. B. Marshall.
1897. Toronto ...	G. F. Deacon, M.Inst.C.E.	Prof. T. Hudson Beare, Prof. Callendar, W. A. Price.
1898. Bristol......	Sir J. Wolfe-Barry, K.C.B., F.R.S.	Prof. T. H. Beare, Prof. J. Munro, H. W. Pearson, W. A. Price.
1899. Dover	Sir W. White, K.C.B., F.R.S.	Prof. T. H. Beare, W. A. Price, H. E. Stilgoe.
1900. Bradford ...	Sir Alex. R. Binnie, M.Inst. C.E.	Prof. T. H. Beare, C. F. Charnock, Prof. S. Dunkerley, W. A. Price.
1901. Glasgow ...	R. E. Crompton, M.Inst.C.E.	H. Bamford, W. E. Dalby, W. A. Price.

SECTION H.—ANTHROPOLOGY.

1884. Montreal...	E. B. Tylor, D.C.L., F.R.S. ...	G. W. Bloxam, W. Hurst.
1885. Aberdeen...	Francis Galton, M.A., F.R.S.	G. W. Bloxam, Dr. J. G. Garson, W. Hurst, Dr. A. Macgregor.
1886. Birmingham	Sir G. Campbell, K.C.S.I., M.P., D.C.L., F.R.G.S.	G. W. Bloxam, Dr. J. G. Garson, W. Hurst, Dr. R. Saundby.
1887. Manchester	Prof. A. H. Sayce, M.A.	G. W. Bloxam, Dr. J. G. Garson, Dr. A. M. Paterson.
1888. Bath.........	Lieut.-General Pitt-Rivers, D.C.L., F.R.S.	G. W. Bloxam, Dr. J. G. Garson, J. Harris Stone.
1889. Newcastle-upon-Tyne	Prof. Sir W. Turner, M.B., LL.D., F.R.S.	G. W. Bloxam, Dr. J. G. Garson, Dr. R. Morison, Dr. R. Howden.
1890. Leeds	Dr. J. Evans, Treas. R.S., F.S.A., F.L.S., F.G.S.	G. W. Bloxam, Dr. C. M. Chadwick, Dr. J. G. Garson.
1891. Cardiff......	Prof. F. Max Müller, M.A. ...	G. W. Bloxam, Prof. R. Howden, H. Ling Roth, E. Seward.
1892. Edinburgh	Prof. A. Macalister, M.A., M.D., F.R.S.	G. W. Bloxam, Dr. D. Hepburn, Prof. R. Howden, H. Ling Roth.
1893. Nottingham	Dr. R. Munro, M.A., F.R.S.E.	G. W. Bloxam, Rev. T. W. Davies, Prof. R. Howden, F. B. Jevons, J. L. Myres.
1894. Oxford......	Sir W. H. Flower, K.C.B., F.R.S.	H. Balfour, Dr. J. G. Garson, H. Ling Roth.
1895. Ipswich ...	Prof. W. M. Flinders Petrie, D.C.L.	J. L. Myres, Rev. J. J. Raven, H. Ling Roth.
1896. Liverpool...	Arthur J. Evans, F.S.A.	Prof. A. C. Haddon, J. L. Myres, Prof. A. M. Paterson.
1897. Toronto ...	Sir W. Turner, F.R.S.	A. F. Chamberlain, H. O. Forbes, Prof. A. C. Haddon, J. L. Myres.

Date and Place	Presidents	Secretaries
1898. Bristol	E. W. Brabrook, C.B.	H. Balfour, J. L. Myres, G. Parker.
1899. Dover	C. H. Read, F.S.A.	H. Balfour, W. H. East, Prof. A. C. Haddon, J. L. Myres.
1900. Bradford ...	Prof. John Rhys, M.A..	Rev. E. Armitage, H. Balfour, W. Crooke, J. L. Myres.
1901. Glasgow ...	Prof. D. J. Cunningham, F.R.S.	W. Crooke, Prof. A. F. Dixon, J. F. Gemmill, J. L. Myres.

SECTION I.—PHYSIOLOGY (including Experimental Pathology and Experimental Psychology).

1894. Oxford......	Prof. E. A. Schäfer, F.R.S., M.R.C.S.	Prof. F. Gotch, Dr. J. S. Haldane, M. S. Pembrey.
1896. Liverpool...	Dr. W. H. Gaskell, F.R.S.	Prof. R. Boyce, Prof. C. S. Sherrington.
1897. Toronto ...	Prof. Michael Foster, F.R.S.	Prof. R. Boyce, Prof. C. S. Sherrington, Dr. L. E. Shore.
1899. Dover	J. N. Langley, F.R.S.	Dr. Howden, Dr. L. E. Shore, Dr. E. H. Starling.
1901. Glasgow ...	Prof. J. G. McKendrick.	W. B. Brodie, W. A. Osborne, Prof. W. H. Thompson.

SECTION K.—BOTANY.

1895. Ipswich ...	W. T. Thiselton-Dyer, F.R.S.	A. C. Seward, Prof. F. E. Weiss.
1896. Liverpool...	Dr. D. H. Scott, F.R.S.	Prof. Harvey Gibson, A. C. Seward, Prof. F. E. Weiss.
1897. Toronto ...	Prof. Marshall Ward, F.R.S.	Prof. J. B. Farmer, E. C. Jeffrey, A. C. Seward, Prof. F. E. Weiss.
1898. Bristol......	Prof. F. O. Bower, F.R.S.	A. C. Seward, H. Wager, J. W. White.
1899. Dover	Sir George King, F.R.S.	G. Dowker, A. C. Seward, H. Wager.
1900. Bradford .	Prof. S. H. Vines, F.R.S.......	A. C. Seward, H. Wager, W. West.
1901. Glasgow .	Prof. I. B. Balfour, F.R.S. ...	G. F. Scott Elliot, D. T. Gwynne-Vaughan, A. C. Seward, H. Wager.

SECTION L.—EDUCATIONAL SCIENCE.

1901. Glasgow ...	Sir John E. Gorst, F.R.S.	R. A. Gregory, W. M. Heller, R. Y. Howie, C. W. Kimmins, Prof. H. L. Withers.

LIST OF EVENING DISCOURSES.

Date and Place	Lecturer	Subject of Discourse
1842. Manchester	Charles Vignoles, F.R.S......	The Principles and Construction of Atmospheric Railways.
	Sir M. I. Brunel	The Thames Tunnel.
	R. I. Murchison..	The Geology of Russia.
1843. Cork .	Prof. Owen, M.D., F.R.S.......	The Dinornis of New Zealand.
	Prof. E. Forbes, F.R.S..........	The Distribution of Animal Life in the Ægean Sea.
	Dr. Robinson.....................	The Earl of Rosse's Telescope.
1844. York .	Charles Lyell, F.R.S.	Geology of North America.
	Dr. Falconer, F.R.S.............	The Gigantic Tortoise of the Siwalik Hills in India.
1845. Cambridge	G.B.Airy, F.R.S., Astron.Royal	Progress of Terrestrial Magnetism

Date and Place	Lecturer	Subject of Discourse
1845. Cambridge	R. I. Murchison, F.R.S. ..	Geology of Russia.
1846. Southampton.	Prof. Owen, M.D., F.R.S.	Fossil Mammalia of the British Isles.
	Charles Lyell, F.R.S.	Valley and Delta of the Mississippi.
	W. R. Grove, F.R.S.	Properties of the Explosive Substance discovered by Dr. Schönbein; also some Researches of his own on the Decomposition of Water by Heat.
1847. Oxford......	Rev. Prof. B. Powell, F.R.S.	Shooting Stars.
	Prof. M. Faraday, F.R.S......	Magnetic and Diamagnetic Phenomena.
1848. Swansea	Hugh E. Strickland, F.G.S...	The Dodo (*Didus ineptus*).
	John Percy, M.D., F.R.S......	Metallurgical Operations of Swansea and its Neighbourhood.
	W. Carpenter, M.D., F.R.S...	Recent Microscopical Discoveries.
1849. Birmingham	Dr. Faraday, F.R.S.	Mr. Gassiot's Battery.
	Rev. Prof. Willis, M.A., F.R.S.	Transit of different Weights with varying Velocities on Railways.
1850. Edinburgh	Prof. J. H. Bennett, M.D., F.R.S.E.	Passage of the Blood through the minute vessels of Animals in connection with Nutrition.
	Dr. Mantell, F.R.S.	Extinct Birds of New Zealand.
1851. Ipswich	Prof. R. Owen, M.D., F.R.S.	Distinction between Plants and Animals, and their changes of Form.
	G.B.Airy, F.R.S., Astron. Royal	Total Solar Eclipse of July 28, 1851.
1852. Belfast..	Prof. G. G. Stokes, D.C.L., F.R.S.	Recent Discoveries in the properties of Light.
	Colonel Portlock, R.E., F.R.S.	Recent Discovery of Rock-salt at Carrickfergus, and geological and practical considerations connected with it.
1853. Hull.	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	Some peculiar Phenomena in the Geology and Physical Geography of Yorkshire.
	Robert Hunt, F.R.S............	The present state of Photography.
1854. Liverpool...	Prof. R. Owen, M.D., F.R.S.	Anthropomorphous Apes.
	Col. E. Sabine, V.P.R.S.	Progress of Researches in Terrestrial Magnetism.
1855. Glasgow	Dr. W. B. Carpenter, F.R.S.	Characters of Species.
	Lieut.-Col. H. Rawlinson ..	Assyrian and Babylonian Antiquities and Ethnology.
1856. Cheltenham	Col. Sir H. Rawlinson.	Recent Discoveries in Assyria and Babylonia, with the results of Cuneiform Research up to the present time.
	W. R. Grove, F.R.S.	Correlation of Physical Forces.
1857. Dublin......	Prof. W. Thomson, F.R.S. ...	The Atlantic Telegraph.
	Rev. Dr. Livingstone, D.C.L.	Recent Discoveries in Africa.
1858. Leeds	Prof. J. Phillips, LL.D., F.R.S.	The Ironstones of Yorkshire.
	Prof. R. Owen, M.D., F.R.S.	The Fossil Mammalia of Australia.
1859. Aberdeen...	Sir R. I. Murchison, D.C.L....	Geology of the Northern Highlands.
	Rev. Dr. Robinson, F.R.S. ...	Electrical Discharges in highly rarefied Media.
1860. Oxford......	Rev. Prof. Walker, F.R.S. ...	Physical Constitution of the Sun.
	Captain Sherard Osborn, R.N.	Arctic Discovery.
1861. Manchester	Prof. W. A. Miller, M.A., F.R.S.	Spectrum Analysis.
	G. B. Airy, F.R.S., Astron. Royal.	The late Eclipse of the Sun.
1862. Cambridge	Prof. Tyndall, LL.D., F.R.S.	The Forms and Action of Water.
	Prof. Odling, F.R.S.	Organic Chemistry.

Date and Place	Lecturer	Subject of Discourse
1863. Newcastle	Prof. Williamson, F.R.S...	The Chemistry of the Galvanic Battery considered in relation to Dynamics.
	James Glaisher, F.R.S...	The Balloon Ascents made for the British Association.
1864. Bath........	Prof. Roscoe, F.R.S.......	The Chemical Action of Light.
	Dr. Livingstone, F.R.S.	Recent Travels in Africa.
1865. Birmingham	J. Beete Jukes, F.R.S....	Probabilities as to the position and extent of the Coal-measures beneath the red rocks of the Midland Counties.
1866. Nottingham	William Huggins, F.R.S.......	The results of Spectrum Analysis applied to Heavenly Bodies.
	Dr. J. D. Hooker, F.R.S.......	Insular Floras.
1867. Dundee..	Archibald Geikie, F.R.S.......	The Geological Origin of the present Scenery of Scotland.
	Alexander Herschel, F.R.A.S.	The present state of Knowledge regarding Meteors and Meteorites.
1868. Norwich	J. Fergusson, F.R.S............	Archæology of the early Buddhist Monuments.
	Dr. W. Odling, F.R.S.	Reverse Chemical Actions.
1869. Exeter	Prof. J. Phillips, LL.D., F.R.S.	Vesuvius
	J. Norman Lockyer, F.R.S.	The Physical Constitution of the Stars and Nebulæ.
1870. Liverpool...	Prof. J. Tyndall, LL.D., F.R.S.	The Scientific Use of the Imagination.
	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	Stream-lines and Waves, in connection with Naval Architecture.
1871. Edinburgh	F. A. Abel, F.R.S...............	Some Recent Investigations and Applications of Explosive Agents.
	E. B. Tylor, F.R.S.	The Relation of Primitive to Modern Civilisation.
1872. Brighton ...	Prof. P. Martin Duncan, M.B., F.R.S.	Insect Metamorphosis.
	Prof. W. K. Clifford	The Aims and Instruments of Scientific Thought.
1873. Bradford ...	Prof. W. C. Williamson, F.R.S.	Coal and Coal Plants.
	Prof. Clerk Maxwell, F.R.S.	Molecules.
1874. Belfast......	Sir John Lubbock, Bart., M.P., F.R.S.	Common Wild Flowers considered in relation to Insects.
	Prof. Huxley, F.R.S.	The Hypothesis that Animals are Automata, and its History.
1875. Bristol	W. Spottiswoode, LL.D., F.R.S.	The Colours of Polarised Light.
	F. J. Bramwell, F.R.S..........	Railway Safety Appliances.
1876. Glasgow ...	Prof. Tait, F.R.S.E.	Force.
	Sir Wyville Thomson, F.R.S.	The 'Challenger' Expedition.
1877. Plymouth...	W. Warington Smyth, M.A., F.R.S.	Physical Phenomena connected with the Mines of Cornwall and Devon.
	Prof. Odling, F.R.S............	The New Element, Gallium.
1878. Dublin	G. J. Romanes, F.L.S.	Animal Intelligence.
	Prof. Dewar, F.R.S.	Dissociation, or Modern Ideas of Chemical Action.
1879. Sheffield ...	W. Crookes, F.R.S.	Radiant Matter.
	Prof. E. Ray Lankester, F.R.S.	Degeneration.
1880. Swansea	Prof. W. Boyd Dawkins, F.R.S.	Primeval Man.
	Francis Galton, F.R.S..........	Mental Imagery.
1881. York..	Prof. Huxley, Sec. R.S.	The Rise and Progress of Palæontology.
	W. Spottiswoode, Pres. R.S....	The Electric Discharge, its Forms and its Functions.

Date and Place	Lecturer	Subject of Discourse
1882. Southampton.	Prof. Sir Wm. Thomson, F.R.S.	Tides.
	Prof. H. N. Moseley, F.R.S.	Pelagic Life.
1883. Southport	Prof. R. S. Ball, F.R.S.	Recent Researches on the Distance of the Sun.
	Prof. J. G. McKendrick.	Galvanic and Animal Electricity.
1884. Montreal..	Prof. O J. Lodge, D.Sc.	Dust.
	Rev. W. H. Dallinger, F.R.S.	The Modern Microscope in Researches on the Least and Lowest Forms of Life.
1885. Aberdeen...	Prof. W. G. Adams, F.R.S. ...	The Electric Light and Atmospheric Absorption.
	John Murray, F.R.S.E..........	The Great Ocean Basins.
1886. Birmingham	A. W. Rücker, M.A., F.R.S.	Soap Bubbles.
	Prof. W. Rutherford, M.D. ...	The Sense of Hearing.
1887. Manchester	Prof. H. B. Dixon, F.R.S. ...	The Rate of Explosions in Gases.
	Col. Sir F. de Winton	Explorations in Central Africa.
1888. Bath.........	Prof. W. E. Ayrton, F.R.S. ...	The Electrical Transmission of Power.
	Prof. T. G. Bonney, D.Sc., F.R.S.	The Foundation Stones of the Earth's Crust.
1889. Newcastle-upon-Tyne	Prof. W. C. Roberts-Austen, F.R.S.	The Hardening and Tempering of Steel.
	Walter Gardiner, M.A.........	How Plants maintain themselves in the Struggle for Existence.
1890. Leeds	E. B. Poulton, M.A., F.R.S....	Mimicry.
	Prof. C. Vernon Boys, F.R.S.	Quartz Fibres and their Applications.
1891. Cardiff	Prof. L. C. Miall, F.L.S., F.G.S.	Some Difficulties in the Life of Aquatic Insects.
	Prof. A. W. Rücker, M.A., F.R.S.	Electrical Stress.
1892. Edinburgh	Prof. A. M. Marshall, F.R.S.	Pedigrees.
	Prof. J. A. Ewing, M.A., F.R.S.	Magnetic Induction.
1893. Nottingham	Prof. A. Smithells. B.Sc.	Flame.
	Prof. Victor Horsley, F.R.S.	The Discovery of the Physiology of the Nervous System.
1894. Oxford..	J. W. Gregory, D.Sc., F.G.S.	Experiences and Prospects of African Exploration.
	Prof. J. Shield Nicholson, M.A.	Historical Progress and Ideal Socialism.
1895. Ipswich	Prof. S. P. Thompson, F.R.S.	Magnetism in Rotation.
	Prof. Percy F. Frankland, F.R.S.	The Work of Pasteur and its various Developments.
1896. Liverpool.	Dr. F. Elgar, F.R.S............	Safety in Ships.
	Prof. Flinders Petrie, D.C.L.	Man before Writing.
1897. Toronto ...	Prof. Roberts Austen, F.R.S.	Canada's Metals.
	J. Milne, F.R.S...................	Earthquakes and Volcanoes.
1898. Bristol......	Prof. W. J. Sollas, F.R.S. ..	Funafuti: the Study of a Coral Island.
	Herbert Jackson	Phosphorescence.
1899. Dover	Prof. Charles Richet...........	La vibration nerveuse.
	Prof. J. Fleming, F.R.S.	The Centenary of the Electric Current.
1900. Bradford ...	Prof. F. Gotch, F.R.S...........	Animal Electricity.
	Prof. W. Stroud.	Range Finders.
1901. Glasgow ...	Prof. W. Ramsay, F.R.S.......	The Inert Constituents of the Atmosphere.
	F. Darwin, F.R.S.	The Movements of Plants.

LECTURES TO THE OPERATIVE CLASSES.

Date and Place	Lecturer	Subject of Discourse
1867. Dundee....	Prof. J. Tyndall, LL.D., F.R.S.	Matter and Force.
1868. Norwich .	Prof. Huxley, LL.D., F.R.S.	A Piece of Chalk.
1869. Exeter	Prof. Miller, M.D., F.R.S. ...	The modes of detecting the Composition of the Sun and other Heavenly Bodies by the Spectrum.
1870. Liverpool...	Sir John Lubbock, Bart., F.R.S.	Savages.
1872. Brighton ...	W. Spottiswoode, LL.D., F.R.S.	Sunshine, Sea, and Sky.
1873. Bradford ...	C. W. Siemens, D.C.L., F.R.S.	Fuel.
1874. Belfast	Prof. Odling, F.R.S............	The Discovery of Oxygen.
1875. Bristol	Dr. W. B. Carpenter, F.R.S.	A Piece of Limestone.
1876. Glasgow ...	Commander Cameron, C.B....	A Journey through Africa.
1877. Plymouth...	W. H. Preece.	Telegraphy and the Telephone.
1879. Sheffield	W. E. Ayrton	Electricity as a Motive Power.
1880. Swansea	H. Seebohm, F.Z.S.	The North-East Passage.
1881. York......	Prof. Osborne Reynolds, F.R.S.	Raindrops, Hailstones, and Snowflakes.
1882. Southampton.	John Evans, D.C.L., Treas. R.S.	Unwritten History, and how to read it.
1883. Southport	Sir F. J. Bramwell, F.R.S. ...	Talking by Electricity—Telephones.
1884. Montreal ...	Prof. R. S. Ball, F.R.S.........	Comets.
1885. Aberdeen ...	H. B. Dixon, M.A.	The Nature of Explosions.
1886. Birmingham	Prof. W. C. Roberts-Austen, F.R.S.	The Colours of Metals and their Alloys.
1887. Manchester	Prof. G. Forbes, F.R.S.	Electric Lighting.
1888. Bath.........	Sir John Lubbock, Bart., F.R.S.	The Customs of Savage Races.
1889. Newcastle-upon-Tyne	B. Baker, M.Inst.C.E.	The Forth Bridge.
1890. Leeds	Prof. J. Perry, D.Sc., F.R.S.	Spinning Tops.
1891. Cardiff......	Prof. S. P. Thompson, F.R.S.	Electricity in Mining.
1892. Edinburgh	Prof. C. Vernon Boys, F.R.S.	Electric Spark Photographs.
1893. Nottingham	Prof. Vivian B. Lewes.	Spontaneous Combustion.
1894. Oxford......	Prof. W. J. Sollas, F.R.S.	Geologies and Deluges.
1895. Ipswich ...	Dr. A. H. Fison.	Colour.
1896. Liverpool...	Prof. J. A. Fleming, F.R.S....	The Earth a Great Magnet.
1897. Toronto ...	Dr. H. O. Forbes	New Guinea.
1898. Bristol......	Prof. E. B. Poulton, F.R.S.	The ways in which Animals Warn their enemies and Signal to their friends.
1900. Bradford ...	Prof. S. P. Thompson, F.R.S.	Electricity in the Industries.
1901. Glasgow	H. J. Mackinder, M.A..	The Movements of Men by Land and Sea.

OFFICERS OF SECTIONAL COMMITTEES PRESENT AT THE GLASGOW MEETING.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE.

President.—Major P. A. MacMahon, F.R.S., F.R.A.S.

Vice-Presidents.—Prof. A. Gray, LL.D., F.R.S. ; Prof. A. G. Greenhill, F.R.S. ; E. H. Griffiths, M.A., F.R.S. ; Prof. W. Jack, LL.D. ; Lord Kelvin, F.R.S. ; Joseph Larmor, D.Sc., F.R.S. ; Prof. G. Mittag-Leffler, For. Mem. R.S. ; Prof. G. Quincke, For. Mem. R.S. ; Prof. H. H. Turner, F.R.S.

Secretaries.—H. S. Carslaw, M.A., D.Sc. ; C. H. Lees, D.Sc. (*Recorder*) ; W. Stewart, M.A., D.Sc. ; Prof. L. R. Wilberforce, M.A.

SECTION B.—CHEMISTRY.

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Vice-Presidents.—Dr. E. Divers, F.R.S. ; Prof. J. Fergusson, LL.D., F.R.S.E. ; Prof. W. H. Perkin, F.R.S. ; Prof. James Walker, F.R.S. ; Dr. T. E. Thorpe, F.R.S. ; Dr. W. A. Tilden, F.R.S. ; Prof. A. Michael ; Prof. E. W. Morley.

Secretaries.—Dr. W. C. Anderson, M.A. ; Dr. G. G. Henderson, M.A. ; Prof. W. J. Pope ; Dr. T. K. Rose (*Recorder*).

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Secretaries.—J. Graham Kerr, M.A. (*Recorder*) ; James Rankin, M.B., B.Sc. ; J. Y. Simpson, D.Sc.

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Secretaries.—H. N. Dickson, B.Sc., F.R.S.E., F.R.G.S. (*Recorder*) ; Edward Heawood, M.A., F.R.G.S. ; G. Sandeman ; A. Crosby Turner.

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President.—Sir Robert Giffen, K.C.B., F.R.S.

Vice-Presidents.—J. Bonar, LL.D.; Rev. W. Cunningham, D.D., LL.D.; Major P. G. Craigie, V.P.S.S.; L. L. Price, M.A.; Prof. W. Smart, LL.D.

Secretaries.—W. W. Blackie, B.Sc.; A. L. Bowley, M.A.; E. Cannan, LL.D. (*Recorder*); Prof. S. J. Chapman, M.A.

SECTION G.—ENGINEERING.

President.—Colonel R. E. Crompton, M.Inst.C.E.

Vice-Presidents.—Prof. Archibald Barr, D.Sc., M.Inst.C.E.; Prof. T. Hudson Beare, F.R.S.E., M.Inst.C.E.; Sir Alexander R. Binnie, M.Inst.C.E., F.G.S.; Robert Caird, LL.D.; H. Graham Harris, M.Inst.C.E.

Secretaries.—Harry Bamford, M.Sc.; Prof. W. E. Dalby, M.A.; W. A. Price, M.A. (*Recorder*).

SECTION H.—ANTHROPOLOGY.

President.—Prof. D. J. Cunningham, M.D., D.Sc., F.R.S.

Vice-Presidents.—H. Balfour, M.A.; Prof. J. Cleland, M.D., F.R.S.

Secretaries.—W. Crooke; J. F. Gemmill, M.A., M.D.; Prof. A. F. Dixon, Sc.D.; J. L. Myres, M.A., F.S.A. (*Recorder*).

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President.—Prof. J. G. M'Kendrick, M.D., LL.D., F.R.S.

Vice-Presidents.—Prof. A. E. Schäfer, F.R.S.; Prof. C. S. Sherrington, M.D., F.R.S.; Sir M. Foster, K.C.B., M.P., Sec.R.S.; Sir J. Burdon Sanderson, Bart., F.R.S.; Prof. F. Gotch, F.R.S.

Secretaries.—W. B. Brodie, M.B.; W. A. Osborne, D.Sc.; Prof. W. H. Thompson, M.D. (*Recorder*).

SECTION K.—BOTANY.

President.—Prof. I. Bayley Balfour, F.R.S.

Vice-Presidents.—Prof. F. O. Bower, F.R.S.; F. Darwin, F.R.S.; Dr. D. H. Scott, F.R.S.; Prof. J. W. H. Trail, F.R.S.; Prof. Marshall Ward, F.R.S.

Secretaries.—A. C. Seward, F.R.S. (*Recorder*); Prof. G. F. Scott Elliot; D. T. Gwynne-Vaughan; Harold Wager.

SECTION L.—EDUCATIONAL SCIENCE.

President.—The Right Hon. Sir John E. Gorst, K.C., M.P., F.R.S.

Vice-Presidents.—Prof. H. E. Armstrong, F.R.S.; Dr. J. H. Gladstone, F.R.S.; Prof. L. C. Miall, F.R.S.; Prof. John Perry, F.R.S.; The Very Rev. Principal Story, D.D.; Sir John Neilson Cuthbertson, LL.D., D.L.; Sir Philip Magnus.

Secretaries.—Prof. R. A. Gregory; W. M. Heller, B.Sc.; Robert Y. Howie, M.A.; Dr. C. W. Kimmins; Prof. H. L. Withers, M.A. (*Recorder*).

COMMITTEE OF RECOMMENDATIONS.

The President; the Vice-Presidents of the Meeting; the Presidents of former years; the Trustees; the General and Assistant General Secretaries; the General Treasurer.

The Presidents of the Sections.

Prof. A. R. Forsyth; Prof. Schuster; Prof. H. H. Turner; Dr. Thorpe; Prof. Harold Dixon; W. Whitaker; G. W. Lamplugh; Prof. Miall; W. E. Hoyle; Dr. J. Scott Keltie; E. W. Brabrook; E. Cannan; Sir W. H. Preece; Prof. T. H. Beare; H. Balfour; J. L. Myres; Prof. F. Gotch; Prof. Waymouth Reid; Prof. F. O. Bower; Prof. Marshall Ward; Prof. H. E. Armstrong; Dr. C. W. Kimmins; F. W. Rudler.

Dr. THE GENERAL TREASURER'S ACCOUNT,

1900–1901. RECEIPTS.

	£	s.	d.
Balance brought forward	713	6	5
Life Compositions (including Transfers)	267	0	0
New Annual Members' Subscriptions	110	0	0
Annual Subscriptions	557	0	0
Sale of Associates' Tickets	794	0	0
Sale of Ladies' Tickets	481	0	0
Sale of Publications	147	2	5
Sale of Consols	999	8	6
Dividend on Consols	190	3	2
Dividend on India 3 per Cents	102	12	0
Interest on Deposit at Bradford District Bank	37	6	11
Unexpended Balance of Grant returned by Committee on Electrolytic Quantitative Analysis	3	8	4
	£920	17	9

Investments.

	£	s.	d.
Consols	6501	10	5
India 3 per Cents	3600	0	0
	£10,101	10	5

CAREY FOSTER, *General Treasurer.*

900-1901. EXPENDITURE.		£	s.	d.
Expenses of Bradford Meeting, including Printing, Advertising, Payment of Clerks, &c. &c.		131	1	4
Rent and Office Expenses		56	7	8
Salaries		515	0	0
Printing, Binding, &c.		1096	7	9
Payment of Grants made at Bradford:				

	£	s.	d.
Electrical Standards	45	0	0
Seismological Observations	75	0	0
Wave-length Tables	4	11	0
Isomorphous Sulphonic Derivatives of Benzene	35	0	0
Life-zones in British Carboniferous Rocks	20	0	0
Underground Water of North-west Yorkshire	50	0	0
Exploration of Irish Caves	15	0	0
Table at the Zoological Station, Naples	100	0	0
Table at the Biological Laboratory, Plymouth	20	0	0
Index Generum et Specierum Animalium	75	0	0
Migration of Birds	10	0	0
Terrestrial Surface Waves	5	0	0
Changes of Land-level in the Phlegræan Fields	50	0	0
Legislation regulating Women's Labour	15	0	0
Small Screw Gauge	45	0	0
Resistance of Road Vehicles to Traction	75	0	0
Silchester Excavation	10	0	0
Ethnological Survey of Canada	30	0	0
Anthropological Teaching	5	0	0
Exploration in Crete	145	0	0
Physiological Effects of Peptone	30	0	0
Chemistry of Bone Marrow	5	15	11
Suprarenal Capsules in the Rabbit	5	0	0
Fertilisation in Phæophyceæ	15	0	0
Morphology, Ecology, and Taxonomy of Podostemaceæ	20	0	0
Corresponding Societies Committee	15	0	0
	920	**9**	**11**

In hands of General Treasurer:

	£	s.	d.	£	s.	d.
At Bank of England, Western Branch	357	5	8			
Less Cheques not presented	211	11	4			
	145	14	4			
On Deposit at Bradford District Bank	1532	3	1			
Cash	6	13	8			
				1684	11	1
				£4403	**17**	**9**

I have examined the above Account with the books and vouchers of the Association, and certify the same to be correct. I have also verified the balance at the Bankers', and have ascertained that the Investments are registered in the names of the Trustees.

Approved—
E. W. Brabrook, Horace T. Brown, } *Auditors.*

W. B. Keen, *Chartered Accountant*,
3 Church Court, Old Jewry, E.C
July 26, 1901.

1901,

Table showing the Attendance and Receipts

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1831, Sept. 27	York	The Earl Fitzwilliam, D.C.L., F.R.S.	—	—
1832, June 19	Oxford	The Rev. W. Buckland, F.R.S.	—	—
1833, June 25	Cambridge	The Rev. A. Sedgwick, F.R.S.	—	—
1834, Sept. 8	Edinburgh	Sir T. M. Brisbane, D.C.L., F.R.S.	—	—
1835, Aug. 10	Dublin	The Rev. Provost Lloyd, LL.D., F.R.S.	—	—
1836, Aug. 22	Bristol	The Marquis of Lansdowne, F.R.S.	—	—
1837, Sept. 11	Liverpool	The Earl of Burlington, F.R.S.	—	—
1838, Aug. 10	Newcastle-on-Tyne	The Duke of Northumberland, F.R.S.	—	—
1839, Aug. 26	Birmingham	The Rev. W. Vernon Harcourt, F.R.S.	—	—
1840, Sept. 17	Glasgow	The Marquis of Breadalbane, F.R.S.	—	—
1841, July 20	Plymouth	The Rev. W. Whewell, F.R.S.	169	65
1842, June 23	Manchester	The Lord Francis Egerton, F.G.S.	303	169
1843, Aug. 17	Cork	The Earl of Rosse, F.R.S.	109	28
1844, Sept. 26	York	The Rev. G. Peacock, D.D., F.R.S.	226	150
1845, June 19	Cambridge	Sir John F. W. Herschel, Bart., F.R.S.	313	36
1846, Sept. 10	Southampton	Sir Roderick I. Murchison, Bart., F.R.S.	241	10
1847, June 23	Oxford	Sir Robert H. Inglis, Bart., F.R.S.	314	18
1848, Aug. 9	Swansea	The Marquis of Northampton, Pres. R.S.	149	3
1849, Sept. 12	Birmingham	The Rev. T. R. Robinson, D.D., F.R.S.	227	12
1850, July 21	Edinburgh	Sir David Brewster, K.H., F.R.S.	235	9
1851, July 2	Ipswich	G. B. Airy, Astronomer Royal, F.R.S.	172	8
1852, Sept. 1	Belfast	Lieut.-General Sabine, F.R.S.	164	10
1853, Sept. 3	Hull	William Hopkins, F.R.S.	141	13
1854, Sept. 20	Liverpool	The Earl of Harrowby, F.R.S.	238	23
1855, Sept. 12	Glasgow	The Duke of Argyll, F.R.S.	194	33
1856, Aug. 6	Cheltenham	Prof. C. G. B. Daubeny, M.D., F.R.S.	182	14
1857, Aug. 26	Dublin	The Rev. H. Lloyd, D.D., F.R.S.	236	15
1858, Sept. 22	Leeds	Richard Owen, M.D., D.C.L., F.R.S.	222	42
1859, Sept. 14	Aberdeen	H.R.H. The Prince Consort	184	27
1860, June 27	Oxford	The Lord Wrottesley, M.A., F.R.S.	286	21
1861, Sept. 4	Manchester	William Fairbairn, LL.D., F.R.S.	321	113
1862, Oct. 1	Cambridge	The Rev. Professor Willis, M.A., F.R.S.	239	15
1863, Aug. 26	Newcastle-on-Tyne	Sir William G. Armstrong, C.B., F.R.S.	203	36
1864, Sept. 13	Bath	Sir Charles Lyell, Bart., M.A., F.R.S.	287	40
1865, Sept. 6	Birmingham	Prof. J. Phillips, M.A., LL.D., F.R.S.	292	44
1866, Aug. 22	Nottingham	William R. Grove, Q.C., F.R.S.	207	31
1867, Sept. 4	Dundee	The Duke of Buccleuch, K.C.B., F.R.S.	167	25
1868, Aug. 19	Norwich	Dr. Joseph D. Hooker, F.R.S.	196	18
1869, Aug. 18	Exeter	Prof. G. G. Stokes, D.C.L., F.R.S.	204	21
1870, Sept. 14	Liverpool	Prof. T. H. Huxley, LL.D., F.R.S.	314	39
1871, Aug. 2	Edinburgh	Prof. Sir W. Thomson, LL.D., F.R.S.	246	28
1872, Aug. 14	Brighton	Dr. W. B. Carpenter, F.R.S.	245	36
1873, Sept. 17	Bradford	Prof. A. W. Williamson, F.R.S.	212	27
1874, Aug. 19	Belfast	Prof. J. Tyndall, LL.D., F.R.S.	162	13
1875, Aug. 25	Bristol	Sir John Hawkshaw, F.R.S.	239	36
1876, Sept. 6	Glasgow	Prof. T. Andrews, M.D., F.R.S.	221	35
1877, Aug. 15	Plymouth	Prof. A. Thomson, M.D., F.R.S.	173	19
1878, Aug. 14	Dublin	W. Spottiswoode, M.A., F.R.S.	201	18
1879, Aug. 20	Sheffield	Prof. G. J. Allman, M.D., F.R.S.	184	16
1880, Aug. 25	Swansea	A. C. Ramsay, LL.D., F.R.S.	144	11
1881, Aug. 31	York	Sir John Lubbock, Bart., F.R.S.	272	28
1882, Aug. 23	Southampton	Dr. C. W. Siemens, F.R.S.	178	17
1883, Sept. 19	Southport	Prof. A. Cayley, D.C.L., F.R.S.	203	60
1884, Aug. 27	Montreal	Prof. Lord Rayleigh, F.R.S.	235	20
1885, Sept. 9	Aberdeen	Sir Lyon Playfair, K.C.B., F.R.S.	225	18
1886, Sept. 1	Birmingham	Sir J. W. Dawson, C.M.G., F.R.S.	314	25
1887, Aug. 31	Manchester	Sir H. E. Roscoe, D.C.L., F.R.S.	428	86
1888, Sept. 5	Bath	Sir F. J. Bramwell, F.R.S.	266	36
1889, Sept. 11	Newcastle-on-Tyne	Prof. W. H. Flower, C.B., F.R.S.	277	20
1890, Sept. 3	Leeds	Sir F. A. Abel, C.B., F.R.S.	259	21
1891, Aug. 19	Cardiff	Dr. W. Huggins, F.R.S.	189	24
1892, Aug. 3	Edinburgh	Sir A. Geikie, LL.D., F.R.S.	280	14
1893, Sept. 13	Nottingham	Prof. J. S. Burdon Sanderson, F.R.S.	201	17
1894, Aug. 8	Oxford	The Marquis of Salisbury, K.G., F.R.S.	327	21
1895, Sept. 11	Ipswich	Sir Douglas Galton, K.C.B., F.R.S.	214	13
1896, Sept. 16	Liverpool	Sir Joseph Lister, Bart., Pres. R.S.	330	31
1897, Aug. 18	Toronto	Sir John Evans, K.C.B., F.R.S.	120	8
1898, Sept. 7	Bristol	Sir W. Crookes, F.R.S.	281	19
1899, Sept. 13	Dover	Sir Michael Foster, K.C.B., Sec.R.S.	296	20
1900, Sept. 5	Bradford	Sir William Turner, D.C.L., F.R.S.	267	13
1901, Sept. 11	Glasgow	Prof. A. W. Rücker, D.Sc., Sec.R.S.	310	37

* Ladies were not admitted by purchased tickets until 1843. † Tickets of Admission to Sections o

at Annual Meetings of the Association.

Old nnual mbers	New Annual Members	Asso-ciates	Ladies	Foreigners	Total	Amount received during the Meeting	Grants for Scientific Purposes	Year
—	—	—	—	—	353	—	—	1831
—	—	—	—	—	...	—	—	1832
—	—	—	—	—	900	—	—	1833
—	—	—	—	—	1298	—	£20 0 0	1834
—	—	—	—	—	—	—	167 0 0	1835
—	—	—	—	—	1350	—	435 0 0	1836
—	—	—	—	—	1840	—	922 12 6	1837
—	—	—	1100*	—	2400	—	932 2 2	1838
—	—	—	—	34	1438	—	1595 11 0	1839
—	—	—	—	40	1353	—	1546 16 4	1840
46	317	—	60*	—	891	—	1235 10 11	1841
75	376	33†	331*	28	1315	—	1449 17 8	1842
71	185	—	160	—	—	—	1565 10 2	1843
45	190	9†	260	—	—	—	981 12 8	1844
94	22	407	172	35	1079	—	831 9 9	1845
65	39	270	196	36	857	—	685 16 0	1846
197	40	495	203	53	1320	—	208 5 4	1847
54	25	376	197	15	819	£707 0 0	275 1 8	1848
93	33	447	237	22	1071	963 0 0	159 19 6	1849
128	42	510	273	44	1241	1085 0 0	345 18 0	1850
61	47	244	141	37	710	620 0 0	391 9 7	1851
63	60	510	292	9	1108	1085 0 0	304 6 7	1852
56	57	367	236	6	876	903 0 0	205 0 0	1853
121	121	765	524	10	1802	1882 0 0	380 19 7	1854
142	101	1094	543	26	2133	2311 0 0	480 16 4	1855
104	48	412	346	9	1115	1098 0 0	734 13 9	1856
156	120	900	569	26	2022	2015 0 0	507 15 4	1857
111	91	710	509	13	1698	1931 0 0	618 18 2	1858
125	179	1206	821	22	2564	2782 0 0	684 11 1	1859
177	59	636	463	47	1689	1604 0 0	766 19 6	1860
184	125	1589	791	15	3138	3944 0 0	1111 5 10	1861
150	57	433	242	25	1161	1089 0 0	1293 16 6	1862
154	209	1704	1004	25	3335	3640 0 0	1608 3 10	1863
182	103	1119	1058	13	2802	2965 0 0	1289 15 8	1864
215	149	766	508	23	1997	2227 0 0	1591 7 10	1865
218	105	960	771	11	2303	2469 0 0	1750 13 4	1866
193	118	1163	771	7	2444	2613 0 0	1739 4 0	1867
226	117	720	682	45‡	2004	2042 0 0	1940 0 0	1868
229	107	678	600	17	1856	1931 0 0	1622 0 0	1869
303	195	1103	910	14	2878	3096 0 0	1572 0 0	1870
311	127	976	754	21	2463	2575 0 0	1472 2 6	1871
280	80	937	912	43	2533	2649 0 0	1285 0 0	1872
237	99	796	601	11	1983	2120 0 0	1685 0 0	1873
232	85	817	630	12	1951	1979 0 0	1151 16 0	1874
307	93	884	672	17	2248	2397 0 0	960 0 0	1875
331	185	1265	712	25	2774	3023 0 0	1092 4 2	1876
238	59	446	283	11	1229	1268 0 0	1128 9 7	1877
290	93	1285	674	17	2578	2615 0 0	725 16 6	1878
239	74	529	349	13	1404	1425 0 0	1080 11 11	1879
171	41	389	147	12	915	899 0 0	731 7 7	1880
313	176	1230	514	24	2557	2689 0 0	476 8 1	1881
253	79	516	189	21	1253	1286 0 0	1126 1 11	1882
330	323	952	841	5	2714	3369 0 0	1083 3 3	1883
317	219	826	74	26 & 60 H.§	1777	1855 0 0	1173 4 0	1884
332	122	1053	447	6	2203	2256 0 0	1385 0 0	1885
428	179	1067	429	11	2453	2532 0 0	995 0 6	1886
510	244	1985	493	92	3838	4336 0 0	1186 18 0	1887
399	100	639	509	12	1984	2107 0 0	1511 0 5	1888
412	113	1024	579	21	2437	2441 0 0	1417 0 11	1889
368	92	680	334	12	1775	1776 0 0	789 16 8	1890
341	152	672	107	35	1497	1664 0 0	1029 10 0	1891
413	141	733	439	50	2070	2007 0 0	864 10 0	1892
328	57	773	268	17	1661	1653 0 0	907 15 6	1893
435	69	941	451	77	2321	2175 0 0	583 15 6	1894
290	31	493	261	22	1324	1236 0 0	977 15 5	1895
383	139	1384	873	41	3181	3228 0 0	1104 6 1	1896
286	125	682	100	41	1362	1398 0 0	1059 10 8	1897
327	96	1051	639	33	2446	2399 0 0	1212 0 0	1898
324	68	548	120	27	1403	1328 0 0	1430 14 2	1899
297	45	801	482	9	1915	1801 0 0	1072 10 0	1900
374	131	794	246	20	1912	2046 0 0	945 0 0	1901

‡ Including Ladies. § Fellows of the American Association were admitted as Hon. Members for this Meeting.

PRESIDENT.

PROFESSOR ARTHUR W. RÜCKER, M.A., LL.D., D.Sc., Sec.R.S.

VICE-PRESIDENTS.

The Right Hon. the EARL OF GLASGOW, G.C.M.G.
The Right Hon. the LORD BLYTHSWOOD., LL.D., D.L.
The Right Hon. the LORD KELVIN, G.C.V.O., D.C.L., LL.D., F.R.S.
SAMUEL CHISHOLM, Esq., the Hon. the Lord Provost of Glasgow.
Very Rev. R. HERBERT STORY, D.D., LL.D., the Principal of the University of Glasgow.
Sir JOHN MAXWELL STIRLING-MAXWELL, Bart., M.P., D.L.
Sir ANDREW NOBLE, K.C.B., D.C.L., F.R.S.
Sir ARCHIBALD GEIKIE, D.C.L., LL.D., F.R.S.
Sir W. T. THISELTON-DYER, K.C.M.G., C.I.E., F.R.S.
JAMES PARKER SMITH, Esq., M.P., D.L.
JOHN INGLIS, Esq., LL.D.
Professor JOHN CLELAND, M.D., LL.D., D.Sc., F.R.S.

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Professor JAMES DEWAR, M.A., LL.D., F.R.S.

VICE-PRESIDENTS ELECT.

His Grace the DUKE OF ABERCORN, K.G., H.M. Lieutenant of the County of Donegal.
The MARQUESS OF DUFFERIN AND AVA, K.P., F.R.S., H.M. Lieutenant of the County of Down.
The MARQUESS OF LONDONDERRY, K.G., H.M. Lieutenant of the City of Belfast.
Sir FRANCIS MACNAGHTEN, Bart., H.M. Lieutenant of the County of Antrim.
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The Right Hon. the EARL OF ROSSE, K.P., F.R.S.
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R. KYLE KNOX, LL.D.

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Report of the Council for the Year 1900-1901, *presented to the General Committee at Glasgow on Wednesday, September* 11, 1901.

In presenting their Annual Report the Council have, in the first place, *to inform the General Committee that they resolved that an Address should be presented to the King on his accession to the Throne, and that the following Address was presented by the President on behalf of the* Council :—

To THE KING'S MOST EXCELLENT MAJESTY.

May it please Your Majesty,

We, the President and Council of the British Association for the Advancement of Science, most respectfully desire to be permitted to express to Your Majesty our deepest sympathy in the great loss which Your Majesty and the Empire have sustained by the death of Her Gracious Majesty Queen Victoria.

The British Association will always bear in grateful remembrance the fact that your illustrious Father, His Royal Highness the Prince Consort, to whose scientific knowledge and guidance the Nation owes so much, was pleased to accept the office of President for the Meeting held at Aberdeen in 1859. His Royal Highness then, as in so many other ways, revealed his appreciation of the importance of the advancement of science which has exerted so beneficial an influence throughout Her Majesty's glorious reign.

We confidently and fervently hope that the progress of science will continue during the reign of Your Majesty to promote the prosperity of your people throughout the Empire.

We beg leave to be permitted to offer to Your Majesty the humble expression of our sincere congratulation and loyal homage and devotion on your succession to the throne of your Ancestors.

Signed on behalf of the Council,

WM. TURNER, *President.*

To this Address the following gracious reply has been received :—

Home Office, Whitehall,
March 11, 1901.

SIR,—I am commanded by the King to convey to you His thanks for the Loyal expressions of sympathy and devotion which have been addressed to him by the President and Council of the British Association.

His Majesty is further deeply gratified by the tribute paid to the memory and the influence of His Royal Highness the Prince Consort;

and he fully shares in the hope that the advancement of science, which has been so great a glory of Her Majesty's reign, may be continued throughout His own.

I am, Sir, your obedient Servant,
CHAS. T. RITCHIE.

The President of the British Association for the Advancement of Science, Burlington House, W.

The Council have heard with much regret of the death of Dr. Andrew Stewart, one of the Vice-Presidents-elect for the Glasgow meeting, and the founder of the Adam Smith Chair in the University.

The following reply from the India Office regarding the suggestion made by the Council, that opportunity should be taken to collect Ethnographical information by means of the Indian Census of 1901, has been received:—

India Office, Whitehall, London, S.W.,
December 1900.

SIR,—With reference to your letter of December 1899 and my reply No. R. and S. 3539, of the 16th January, 1900, I am directed to inform you that the Secretary of State for India in Council has now received the remarks of the Government of India on the suggestion of the British Association for the Advancement of Science, that opportunity should be taken to collect ethnographical information by means of the Indian Census of 1901.

2. The Government of India entirely agree with the Secretary of State's recognition of the importance of the investigations which the Association suggested, but find themselves constrained to say that it is impossible (except to the limited extent indicated in paragraph 4 of this letter) to make these investigations by means of, or in connection with, the Census. They consider that the addition to the Census Schedule of Columns relating to even a small number of ethnographic facts would expand it to unwieldy dimensions; the enumerating agency is wholly unfitted to conduct such an inquiry, and the facts recorded by it would be worthless; and they apprehend that there would be grave risk, not only that the accuracy of the entries in the essential columns would be impaired by the additional burden imposed on the enumerators, but also that the unusual nature of the questions asked would give rise to rumours and excite apprehensions which would seriously interfere with the ordinary operations of the Census.

3. The Government of India also deem it impracticable to carry out the suggestion that photographers should be placed at the disposal of the Census officers, as this, besides being very expensive, would hinder the officers' proper duties, and would delay the submission of the reports, which it is desired to complete as soon as possible.

4. With the view, however, of taking action, as far as may be practicable, in the direction of collecting ethnographical information, the Census Commissioner has instructed the Census Superintendents to endeavour, in the districts which they visit, to obtain, from the most trustworthy sources, particulars under uniform headings regarding the history, structure, traditions, and religious and social usages of the various tribes and castes. The Commissioner considers that nothing beyond this can be undertaken in connection with the Census operations, and the Government of India accept his opinion; but they have considered the question how far it is possible and advisable apart from the Census to encourage and assist ethnographic investigations in India, and have submitted a scheme by which it is hoped that in the course of a few years a fairly complete account of the ethnography of the larger provinces may be obtained.

This scheme has received Lord George Hamilton's approval.

I am, Sir, your obedient Servant,
(Signed) A. GODLEY.

Sir Michael Foster, K.C.B., F.R.S., Burlington House, Piccadilly, W.

The Council have nominated Professor John Cleland, F.R.S., Vice-President for the Meeting at Glasgow.

The Council have elected the following men of science, who have attended Meetings of the Association, to be Corresponding Members :—

Professor T. C. Chamberlin, Chicago.
Dr. Yves Delage, Paris.
Professor W. G. Farlow, Harvard.
Professor A. P. N. Franchimont, Leiden.
Professor Philipp Lenard, Kiel.
Professor A. Penck, Vienna.
Gen.-Major Rykatchew, St. Petersburg.

The Council, having received an invitation to appoint Delegates to attend the Ninth Jubilee Celebrations of the University of Glasgow on June 12, 13, and 14, requested the President and the General Secretaries to represent the Association at the Celebrations, and to present the following Address to the University :—

We, the President and Council of the British Association for the Advancement of Science, offer our cordial congratulations to the University of Glasgow on the occasion of the celebration of the four hundred and fiftieth anniversary of the founding of the University.

The British Association has since its birth in 1831 been brought from time to time into close relations with the University of Glasgow. It has on three occasions held highly successful meetings within your City, and is looking forward with pleasurable anticipation to a fourth meeting in the autumn of the present year. The success of these gatherings has been largely due to the earnest co-operation of the able men of science who have filled and adorned the Chairs in the University, three of whom at meetings in other Cities have occupied the Presidential Chair of the Association itself.

In presenting our congratulations we would at the same time express the hope that the University may continue to prosper and to extend in influence and usefulness. The efforts which you are making to add to the Professoriate, to obtain new buildings and appliances for the continued development of your teaching and for the encouragement of research, show that you mean to retain a foremost place amidst the Universities of the United Kingdom.

Signed on behalf of the Council,

WILLIAM TURNER, President.

The Council were invited to appoint Delegates to attend the British Congress on Tuberculosis, which was held on July 22–26, in London.

The Council requested Lord Lister and Sir Michael Foster to represent the Association at the Congress.

The following resolutions referred to the Council by the General Committee have been considered and acted upon :—

(1) That in connection with the Resolution relating to the admission of women to Committees, as well as on general grounds, the Council is requested to reconsider the present mode of electing members of Sectional Committees.

The Council appointed a Committee, consisting of Sir F. J. Bramwell, Professor H. E. Armstrong, Mr. E. H. Griffiths, Mr. A. V. Harcourt

Mr. G. W. Lamplugh, Professor W. A. Tilden, and the General Officers, to report on this Resolution.

In accordance with the recommendation of the Committee, the Council recommend that the present practice of electing members of Sectional Committees be continued subject to the following modification :—

'That any Member of the Association who has intimated the intention of attending a particular Meeting of the Association, and who has already served upon a Committee of a Section, shall be eligible for election as a Member of the Committee of that Section at its first meeting.'

(2) That the Council be requested to consider the appointment of a separate Section for education.

The Council considered this proposal, and resolved that a Section of Educational Science be established, to be entitled Section L, but that the Section shall not necessarily meet each year.

The following resolution, which was passed at the Conference of Delegates at Bradford, and accidentally not forwarded to the Committee of Recommendations, was brought before the Council and considered :—

That the proposed Copyright Bill, so far as it affects the copyright of Scientific Societies in their transactions, and the publication of abstracts of Scientific papers, be referred to the General Committee; and that they be requested to take such action as will protect Scientific Societies.

The Council authorised the General Officers to co-operate with other Societies in regard to the question of copyright if a Bill is again brought before Parliament.

The Report of the Corresponding Societies Committee for the past year, consisting of the list of the Corresponding Societies and the titles of the more important papers, and especially those referring to Local Scientific Investigations, published by those Societies during the year ending June 1, 1901, has been received.

The Corresponding Societies Committee, consisting of Mr. Francis Galton, Mr. W. Whitaker (*Chairman*), Dr. J. G. Garson, Sir J. Evans, Mr. J. Hopkinson, Professor R. Meldola, Professor T. G. Bonney, Mr. T. V. Holmes, Mr. Horace T. Brown, Rev. J. O. Bevan, Professor W. W. Watts, Rev. T. R. R. Stebbing, Mr. C. H. Read, and Mr. F. W. Rudler, is hereby nominated for reappointment by the General Committee.

The Council nominate Mr. F. W. Rudler, Chairman, Mr. W. Whitaker, F.R.S., Vice-Chairman, and Dr. J. G. Garson and Mr. Alexander Somerville, Secretaries, to the Conference of Delegates of Corresponding Societies to be held during the Meeting at Glasgow.

The Council have received Reports from the General Treasurer during the past year, and his accounts from July 1, 1900, to June 30, 1901, which have been audited, are presented to the General Committee.

In accordance with the regulations the retiring Members of the Council will be :—

Mr. Francis Darwin.
Dr. W. H. Gaskell.
Professor L. F. Vernon Harcourt.
Professor E. B. Poulton.
Professor J. M. Thomson.

The Council recommend the re-election of the other ordinary Members of the Council, with the addition of the gentlemen whose names are distinguished by an asterisk in the following list :—

Armstrong, Professor H. E., F.R.S.
Bonar, J., Esq., LL.D.
Bower, Professor F. O., F.R.S.
Callendar, Professor H. L., F.R.S.
Creak, Captain E. W., R.N., F.R.S.
*Darwin, Major L., Sec. R.G.S.
Fremantle, The Hon. Sir C. W., K.C.B.
*Gotch, Professor F., F.R.S.
Halliburton, Professor W. D., F.R.S.
Keltie, J. Scott, Esq., LL.D.
Lankester, Professor E. Ray, F.R.S.
Lockyer, Sir J. Norman, K.C.B., F.R.S.
Lodge, Professor Oliver, F.R.S.
*Macalister, Professor A., F.R.S.
MacMahon, Major P. A., F.R.S.
Marr, J. E., Esq., F.R.S.
*Perkin, Professor W. H., F.R.S.
*Perry, Professor John, F.R.S.
Preece, Sir W. H., K.C.B., F.R.S.
Price, L. L., Esq., M.A.
*Seward, A. C., Esq., F.R.S.
Sollas, Professor W. J., F.R.S.
Tilden, Professor W. A., F.R.S.
Tylor, Professor E. B., F.R.S.
Wolfe-Barry, Sir John, K.C.B., F.R.S.

Committees appointed by the General Committee at the Glasgow Meeting in September 1901.

1. *Receiving Grants of Money.*

Subject for Investigation or Purpose	Members of the Committee	Grants £ s. d.
Making Experiments for improving the Construction of Practical Standards for use in Electrical Measurements. [And balance in hand.]	*Chairman.*—Lord Rayleigh. *Secretary.*—Mr. R. T. Glazebrook. Lord Kelvin, Professors W. E. Ayrton, J. Perry, W. G. Adams, Oliver J. Lodge, and G. Carey Foster, Dr. A. Muirhead, Sir W. H. Preece, Professors J. D. Everett and A. Schuster, Dr. J. A. Fleming, Professor J. J. Thomson, Mr. W. N. Shaw, Dr. J. T. Bottomley, Rev. T. C. Fitzpatrick, Dr. G. Johnstone Stoney, Professor S. P. Thompson, Mr. J. Rennie, Mr. E. H. Griffiths, Professors A. W. Rücker, H. L. Callendar, and Sir W. C. Roberts-Austen, and Mr. G. Matthey.	40 0 0
Seismological Observations.	*Chairman.*—Prof. J. W. Judd. *Secretary.*—Professor J. Milne. Lord Kelvin, Professor T. G. Bonney, Mr. C. V. Boys, Professor G. H. Darwin, Mr. Horace Darwin, Major L. Darwin, Professor J. A. Ewing, Dr. R. T. Glazebrook, Professor C. G. Knott, Professor R. Meldola, Mr. R. D. Oldham, Professor J. Perry, Mr. W. E. Plummer, Professor J. H. Poynting, Mr. Clement Reid, Mr. Nelson Richardson, and Professor H. H. Turner.	75 0 0
To co-operate with the Royal Meteorological Society in initiating an Investigation of the Upper Atmosphere by means of Kites.	*Chairman.*—Mr. W. N. Shaw. *Secretary.*—Mr. W. H. Dines. Mr. D. Archibald, Mr. C. Vernon Boys, Dr. A. Buchan, and Dr. H. R. Mill.	75 0 0
To co-operate with the Committee of the Falmouth Observatory in their Magnetic Observations.	*Chairman.*—Sir W. H. Preece. *Secretary.*—Dr. R. T. Glazebrook. Professor W. G. Adams, Captain Creak, Mr. W. Fox, Professor A. Schuster, and Principal Rücker.	80 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants £ s. d.
The relation between the Absorption Spectra and Chemical Constitution of Organic Substances.	*Chairman* and *Secretary.*—Professor W. Noel Hartley. Professor F. R. Japp, Professor J. J. Dobbie, and Mr. Alexander Lauder.	20 0 0
Preparing a new Series of Wave-length Tables of the Spectra of the Elements.	*Chairman.*—Sir H. E. Roscoe. *Secretary.*—Dr. Marshall Watts. Sir J. N. Lockyer, Professors J. Dewar, G. D. Liveing, A. Schuster, W. N. Hartley, and Wolcott Gibbs, and Sir W. de W. Abney.	5 0 0
The action of Gases dissolved in Metals and Alloys on their Properties.	*Chairman.*—Sir Wm. C. Roberts-Austen. *Secretary.*—Dr. T. K. Rose. Mr. W. Carrick-Anderson, Professor H. B. Dixon, Mr. C. T. Heycock, Mr. F. H. Neville, and Professor W. Ramsay.	40 0 0
The Collection, Preservation, and Systematic Registration of Photographs of Geological Interest.	*Chairman.*—Professor J. Geikie. *Secretary.*—Professor W. W. Watts. Professor T. G. Bonney, Dr. T. Anderson, Professor E. J. Garwood, and Messrs. A. S. Reid, W. Gray, H. B. Woodward, R. Kidston, J. J. H. Teall, J. G. Goodchild, H. Coates, C. V. Crook, G. Bingley, and R. Welch.	5 0 0
To study Life-zones in the British Carboniferous Rocks.	*Chairman.*—Mr. J. E. Marr. *Secretary.*—Dr. Wheelton Hind. Mr. F. A. Bather, Mr. G. C. Crick, Mr. A. H. Foord, Mr. H. Fox, Professor E. J. Garwood, Dr. G. J. Hinde, Professor Percy F. Kendall, Mr. Robert Kidston, Mr. G. W. Lamplugh, Professor G. A. Lebour, Mr. B. N. Peach, Mr. A. Strahan, and Dr. H. Woodward.	10 0 0
The movements of Underground Waters of North-west Yorkshire. [Balance in hand.]	*Chairman.*—Professor W. W. Watts. *Secretary.*—Captain A. R. Dwerryhouse. Professor A. Smithells, Rev. E. Jones, Mr. Walter Morrison, Mr. G. Bray, Mr. W. Lower Carter, Mr. W. Fairley, Professor P. F. Kendall, and Mr. J. E. Marr.	

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants
		£ s. d.
To explore Irish Caves. [Collections to be placed in the Science and Art Museum, Dublin.]	*Chairman.*—Dr. R. F. Scharff. *Secretary.*—Mr. R. Lloyd Praeger. Mr. G. Coffey, Professor Grenville Cole, Dr. Cunningham, Mr. G. W. Lamplugh, Mr. A. McHenry, and Mr R. J. Ussher.	45 0 0
To consider the best Methods for the Registration of all Type Specimens of Fossils in the British Isles, and to report on the same. [Balance in hand.]	*Chairman.*—Dr. H. Woodward. *Secretary.*—Mr. A. Smith Woodward. Rev. G. F. Whidborne, Mr. R. Kidston, Professor H. G. Seeley, Mr. H. Woods, and Rev. J. F. Blake.	—
To enable Mr. R. Gurney to work at Excretion in Crustacea, Mr. Wallace to investigate Viviparous Fishes, and to aid other competent investigator, to carry on definite pieces of work at the Zoological Station at Naples.	*Chairman.*—Professor W. A. Herdman. *Secretary.*—Professor G. B. Howes. Professor E. Ray Lankester, Professor W. F. R. Weldon, Professor S. J. Hickson, Mr. A. Sedgwick, and Professor W. C. McIntosh.	100 0 0
To enable Mr. R. C. Punnett to continue his investigations on the pelvic plexus of Elasmobranch fishes, and to enable other competent naturalists to perform definite pieces of work at the Marine Laboratory, Plymouth. [Balance, 8*l.* 5*s.*, in hand.]	*Chairman.*—Mr. W. Garstang. *Secretary.*—Mr. W. Garstang. Professor E. Ray Lankester, Professor Sydney H. Vines, Mr. A. Sedgwick, and Professor W. F. R. Weldon.	—
Compilation of an Index Generum et Specierum Animalium.	*Chairman.*—Dr. H. Woodward. *Secretary.*—Mr. F. A. Bather. Dr. P. L. Sclater, Rev. T. R. R. Stebbing, Mr. R. McLachlan, and Mr. W. E. Hoyle.	100 0 0
To work out the details of the Observations on the Migration of Birds at Lighthouses and Lightships, 1880–87.	*Chairman.*—Professor A. Newton. *Secretary.*—Rev. E. P. Knubley. Mr. John A. Harvie-Brown, Mr. R. M. Barrington, Mr. A. H. Evans, and Dr. H. O. Forbes.	15 0 0
To investigate the structure, formation, and growth of the Coral Reefs of the Indian Region, with special observations on the inter-relationship of the reef organisms, the depths at which they grow, the food of corals, effects of currents and character of the ocean bottom, &c. The land flora and fauna will be collected, and it is intended that observations shall be made on the manners, &c., of the natives in the different parts of the Maldive group.	*Chairman.*—Mr. A. Sedgwick. *Secretary.*—J. Graham Kerr. Professor J. W. Judd, Mr. J. J. Lister, Mr. Francis Darwin, Dr. S. F. Harmer, Professors A. Macalister, W. A. Herdman, and S. J. Hickson.	50 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants
		£ s. d.
To enable Mr. James Rankin to investigate Compound Ascidians of the Clyde area, and to enable other competent naturalists to perform definite researches in the Laboratory of the Marine Biological Association of the West of Scotland at Millport.	*Chairman.*—Sir John Murray. *Secretary.*—Dr. J. F. Gemmill. Professor F. O. Bower, Professor Cossar Ewart, Professor W. A. Herdman, Professor M. Laurie, Mr. Alex. Somerville, and Mr. J. A. Todd.	25 0 0
Terrestrial Surface-waves and Wave-like Surfaces.	*Chairman.*—Dr. Scott Keltie. *Secretary.*—Colonel F. Bailey. Mr. Vaughan Cornish, Mr. A. R. Hunt, and Mr. W. H. Wheeler.	15 0 0
The Economic Effect of Legislation regulating Women's Labour.	*Chairman.*—Mr. E. W. Brabrook. *Secretary.*—Mr. A. L. Bowley. Miss A. M. Anderson, Mr. C. Booth, Mr. S. J. Chapman, Miss C. E. Collet, Professor Edgeworth, Professor Flux, Mrs. J. R. MacDonald, Mr. L. L. Price, Professor Smart, and Mrs. H. J. Tennant.	30 0 0
To consider means by which better practical effect can be given to the Introduction of the Screw Gauge proposed by the Association in 1884.	*Chairman.*—Sir W. H. Preece. *Secretary.*—Mr. W. A. Price. Lord Kelvin, Sir F. J. Bramwell, Sir H. Trueman Wood, Maj.-Gen. Webber, Mr. R. E. Crompton, Mr. A. Stroh, Mr. A. Le Neve Foster, Mr. C. J. Hewitt, Mr. G. K. B. Elphinstone, Col. Watkin, Mr. E. Rigg, Mr. Vernon Boys, Mr. J. Marshall Gorham, Mr. O. P. Clements, Mr. W. Taylor, and Dr. R. T. Glazebrook.	20 0 0
To investigate the resistance of Road Vehicles to Traction.	*Chairman.*—Sir Alexander Binnie. *Secretary.*—Professor H. S. Hele Shaw. Mr. Aitken, Mr. T. C. Aveling, Professor T. Hudson Beare, Mr. W. W. Beaumont, Mr. J. Brown, Col. R. E. Crompton, Mr. A. Mallock, Sir D. Salomans, Mr. A. Sennett, Mr. Shrapnell Smith, and Mr J. I. Thornycroft.	50 0 0
To co-operate with the Silchester Excavation Fund Committee in their explorations.	*Chairman.*—Mr. A. J. Evans. *Secretary.*—Mr. John L. Myres. Mr. E. W. Brabrook.	0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants £ s. d.
To organise an Ethnological Survey of Canada.	*Chairman.*—Professor D. P. Penhallow. *Secretary.*—Mr. C. Hill-Tout. Mr. E. W. Brabrook, Professor A. C. Haddon, Mr. E. S. Hartland, Sir J. G. Bourinot, Mr. B. Sulte, Mr. David Boyle, Mr. C. N. Bell, Professor E. B. Tylor, Professor J. Mavor, Mr. C. F. Hunter, and Dr. W. F. Ganong.	15 0 0
To conduct Explorations with the object of ascertaining the age of Stone Circles.	*Chairman.*—Dr. J. G. Garson. *Secretary.*—Mr. H. Balfour. Sir John Evans, Mr. C. H. Read, Professor Meldola, Mr. A. J. Evans, Dr. R. Munro, Professor Boyd-Dawkins, and Mr. A. L. Lewis.	30 0 0
The Collection, Preservation, and Systematic Registration of Photographs of Anthropological Interest. [Balance in hand.]	*Chairman.*—Mr. C. H. Read. *Secretary.*—Mr. J. L. Myres. Dr. J. G. Garson, Mr. H. Ling Roth, Mr. H. Balfour, Mr. E. S. Hartland, and Professor Flinders Petrie.	
The Present State of Anthropological Teaching in the United Kingdom and Elsewhere.	*Chairman.*—Professor E. B. Tylor. *Secretary.*—Mr. H. Ling Roth. Professor A. Macalister, Professor A. C. Haddon, Mr. C. H. Read, Mr. H. Balfour, Mr. F. W. Rudler, Dr. R. Munro, and Professor Flinders Petrie.	3 0 0
To conduct Explorations at Knossos in Crete.	*Chairman.*—Sir John Evans. *Secretary.*—Mr. J. L. Myres. Mr. A. J. Evans, Mr. D. G. Hogarth, Professor A. Macalister, and Professor W. Ridgeway.	100 0 0
To conduct Anthropometric Investigations among the Native Troops of the Egyptian Army.	*Chairman.*—Professor A. Macalister. *Secretary.*—Mr. C. S. Myers. Sir John Evans and Professor D. J. Cunningham.	15 0 0
To co-operate with the Cardiff Naturalists' Society in its Excavations on the Roman Site at Gelligaer.	*Chairman.*—Professor J. Rhys. *Secretary.*—Mr. J. L. Myres. Mr. A. J. Evans and Mr. E. W. Brabrook.	5 0 0

1. *Receiving Grants of Money*—continued.

ubject for Investigation or Purpose	Members of the Committee	Grants
		£ s. d.
'o study the power of the Mammalian Heart for performing work under varying external conditions and under the influence of Drugs.	*Chairman.* — Professor J. G. McKendrick. *Secretary.*—Mr. T. Grigor Brodie. Professor W. H. Thompson.	20 0 0
'he changes occurring in Hæmoglobin and the supposed destruction of Red Corpuscles in the Spleen.	*Chairman.* — Professor J. G. McKendrick. *Secretary.*—Mr. W. Brodie Brodie. Professor Ralph Stockman.	15 0 0
Investigation of the Cyanophyceæ.	*Chairman.* — Professor J. B. Farmer. *Secretary.*—Dr. F. F. Blackman. Professor Marshall Ward and Mr. W. Gardiner.	10 0 0
Investigation on the Respiration of Plants.	*Chairman.* — Professor Marshall Ward. *Secretary.*—Mr. H. Wager. Mr. Francis Darwin and Professor J. B. Farmer.	15 0 0
To consider and report upon the influence exercised by Universities and Examining Bodies on secondary school curricula, and also of the schools on university requirements.	*Chairman.*—Dr. H. E. Armstrong. *Secretary.*—Mr. W. H. D. Rouse. The Bishop of Hereford, Sir Michael Foster, Sir P. Magnus, Principal Rücker, Principal Lodge, Mr. H. W. Eve, Mr. W. A. Shenstone, Mr. Eggar, Professor Marshall Ward, Mr. F. H. Neville, Mrs. W. N. Shaw, Professor H. L. Withers, and Dr. C. W. Kimmins.	0 0
The conditions of Health essential to the carrying on of the work of instruction in schools.	*Chairman.*— *Secretary.*—Mr. E. White Wallis. Dr. C. W. Kimmins, Professor L. C. Miall, Professor H. L. Withers, and Professor Sherrington; and that the Council be authorised to appoint a Chairman.	2 0 0
Corresponding Societies Committee for the preparation of their Report.	*Chairman.*—Mr. W. Whitaker. *Secretary.*—Dr. J. G. Garson. Mr. Francis Galton, Professor R. Meldola, Mr. T. V. Holmes, Sir John Evans, Mr. J. Hopkinson, Professor T. G. Bonney, Mr. Horace T. Brown, Rev. J. O. Bevan, Professor W. W. Watts, Rev. T. R. R. Stebbing, Mr. C. H. Read, and Mr. F. W. Rudler.	15 0 0

2. *Not receiving Grants of Money.*

Subject for Investigation or Purpose	Members of the Committee.
Radiation from a Source of Light in a Magnetic Field.	*Chairman.*—Professor A. Schuster. *Secretary.*—Mr. W. E. Thrift. Professor O. J. Lodge, Professor S. P. Thompson, Dr. Gerald Molloy, Dr. W. E. Adeney, and Mr. E. P. Culverwell.
To establish a Meteorological Observatory on Mount Royal, Montreal.	*Chairman.*—Professor H. L. Callendar. *Secretary.*—Professor C. H. McLeod. Professor F. Adams and Mr. R. F. Stupart.
Co-operating with the Scottish Meteorological Society in making Meteorological Observations on Ben Nevis.	*Chairman.*—Lord McLaren. *Secretary.*—Professor Crum Brown. Sir John Murray, Dr. A. Buchan, and Professor R. Copeland.
Comparing and Reducing Magnetic Observations.	*Chairman.*—Professor W. G. Adams. *Secretary.*—Dr. C. Chree. Lord Kelvin, Professor G. H. Darwin, Professor G. Chrystal, Professor A. Schuster, Captain E. W. Creak, the Astronomer Royal, Mr. William Ellis, and Professor A. W. Rücker.
The Rate of Increase of Underground Temperature downwards in various Localities of Dry Land and under Water.	*Chairman.*—Professor J. D. Everett. *Secretary.*—Professor J. D. Everett. Lord Kelvin, Sir Archibald Geikie, Mr. James Glaisher, Professor Edward Hull, Dr. C. Le Neve Foster, Professor A. S. Herschel, Professor G. A. Lebour, Mr. A. B. Wynne, Mr. W. Galloway, Mr. Joseph Dickinson, Mr. G. F. Deacon, Mr. E. Wethered, Mr. A. Strahan, Professor Michie Smith, Professor H. L. Callendar, and Mr. B. H. Brough.
Considering the best Methods of Recording the Direct Intensity of Solar Radiation.	*Chairman.*—Dr. G. Johnstone Stoney. *Secretary.*—Professor H. McLeod. Sir G. G. Stokes, Professor A. Schuster, Sir H. E. Roscoe, Captain Sir W. de W. Abney, Dr. C. Chree, Professor H. L. Callendar, Mr. W. E. Wilson, and Professor A. A. Rambaut.
That Miss Hardcastle be requested to draw up a Report on the present state of the Theory of Point-Groups.	
The Nature of Alloys.	*Chairman and Secretary.*—Mr. F. H. Neville. Mr. C. T. Heycock and Mr. E. H. Griffiths.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee
Isomeric Naphthalene Derivatives.	*Chairman.*—Professor W. A. Tilden. *Secretary.*—Professor H. E. Armstrong.
The Study of Isomorphous Sulphonic Derivatives of Benzene.	*Chairman.*—Professor H. A. Miers. *Secretary.*—Professor H. E. Armstrong. Dr. W. P. Wynne and Mr. W. J. Pope.
To collect Statistics concerning the trained chemists employed in English Chemical Industries.	*Chairman.*—Professor W. H. Perkin. *Secretary.*—Dr. G. G. Henderson. Professor H. E. Armstrong and Mr. G. T. Beilby.
To approach the Inland Revenue Commissioners to urge the desirability of securing the use of pure alcohol duty free for the purposes of scientific research.	*Chairman.*—Sir H. E. Roscoe. *Secretary.*—Professor H. B. Dixon. Sir Michael Foster, Principal Rücker, Dr. T. E. Thorpe, Professor W. H. Perkin, and Professor W. D. Halliburton.
To investigate the Erratic Blocks of the British Isles, and to take measures for their preservation.	*Chairman.*—Mr. J. E. Marr. *Secretary.*—Prof. P. F. Kendall. Professor T. G. Bonney, Mr C. E. De Rance, Professor W. J. Sollas, Mr. R. H. Tiddeman, Rev. S. N. Harrison, Mr. John Horne, Mr. F. M. Burton, Mr. J. Lomas, Mr. A. R. Dwerryhouse, Mr. J. W. Stather, Mr. R. D. Tucker, and Mr. F. W. Harmer.
To report upon the Present State of our Knowledge of the Structure of Crystals.	*Chairman.*—Professor N. Story Maskelyne. *Secretary.*—Professor H. A. Miers. Mr. L. Fletcher, Professor W. J. Sollas, Mr. W. Barlow, Mr. G. F. H. Smith, and the Earl of Berkeley.
The Periodic Investigation of the Plankton and Physical Conditions of the English Channel.	*Chairman.*—Professor E. Ray Lankester. *Secretary.*—Mr. Walter Garstang. Professor W. A. Herdman and Mr. H. N. Dickson.
To continue the investigation of the Zoology of the Sandwich Islands, with power to co-operate with the Committee appointed for the purpose by the Royal Society, and to avail themselves of such assistance in their investigations as may be offered by the Hawaiian Government or the Trustees of the Museum at Honolulu. The Committee to have power to dispose of specimens where advisable.	*Chairman.*—Professor A. Newton. *Secretary.*—Dr. David Sharp. Dr. W. T. Blanford, Professor S. J. Hickson, Dr. P. L. Sclater, Mr. F. Du Cane Godman, and Mr. Edgar A. Smith.
To promote the Systematic Collection of Photographic and other Records of Pedigree Stock.	*Chairman.*—Mr. Francis Galton. *Secretary.*—Professor W. F. R. Weldon. Professor J. C. Ewart, Professor J. A. Thomson, and Professor R. Wallace.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation or Purpose.	Members of the Committee
To examine the Natural History and Ethnography of the Malay Peninsula.	*Chairman.*—Mr. C. H. Read. *Secretary.*—Mr. W. Crooke. Professor A. Macalister, Professor W. Ridgeway, and Dr. H. O. Forbes.
The Lake Village at Glastonbury.	*Chairman.*—Dr. R. Munro. *Secretary.*—Mr. A. Bulleid. Professor W. Boyd Dawkins, Sir John Evans, Mr. Arthur J. Evans, and Mr. C. H. Read.
To organise a Pigmentation Survey of the school children of Scotland.	*Chairman.*—Mr. E. W. Braybrook. *Secretary.*—Mr. J. Gray. Dr. A. C. Haddon, Professor A. Macalister, Professor D. J. Cunningham, Mr. J. F. Tocher, and Dr. W. H. R. Rivers.
The Physiological Effects of Peptone and its Precursors when introduced into the circulation.	*Chairman.*—Professor E. A. Schäfer. *Secretary.*—Professor W. H. Thompson. Professor R. Boyce and Professor C. S. Sherrington.
The Micro-chemistry of Cells.	*Chairman.*—Professor E. A. Schäfer. *Secretary.*—Professor A. B. Macallum. Professor E. Ray Lankester, Professor W. D. Halliburton, Mr. G. C. Bourne, and Professor J. J. Mackenzie.
Fertilisation in Phæophyceæ.	*Chairman.*—Professor J. B. Farmer. *Secretary.*—Professor R. W. Phillips. Professor F. O. Bower and Professor Harvey Gibson.
To consider and report upon a scheme for the registration of negatives of *Botanical Photographs.*	*Chairman.*—Professor L. C. Miall. *Secretary.*—Professor F. E. Weiss. *Mr. Francis Darwin and Professor G. F. Scott Elliot.*
The Teaching of Natural Science in Elementary Schools.	*Chairman.*—Dr. J. H. Gladstone. *Secretary.*—Professor H. E. Armstrong. Lord Avebury, Mr. George Gladstone, Professor W. R. Dunstan, Sir Philip Magnus, Sir H. E. Roscoe, Dr. Silvanus P. Thompson, and Professor A. Smithells.
To report upon improvements that might be effected in the teaching of Mathematics, in the first instance in the teaching of Elementary Mathematics, and upon such means as they think likely to effect such improvements.	*Chairman.*—Professor A. R. Forsyth. *Secretary.*—Professor J. Perry. Principal A. W. Rücker, Principal O. J. Lodge, Major P. MacMahon, Professor W. H. H. Hudson, Dr. J. Larmor, Professor S. P Thompson, Professors G Chrystal, O. Henrici, A. Lodge, A. G Greenhill, G. M. Minchin, Mr. W. D Eggar, Mr. H. W. Eve, Dr. Gladstone, Professor G. Gibson, Professor Robert Russell, and Mr. R. A. Gregory

Resolution relating to Committee on Traction of Vehicles.

That in accordance with the Rules of the Association the Committee on the Resistance of Road Vehicles to Traction be authorised to obtain further subscriptions in aid of its work.

Communications ordered to be printed in extenso.

The Clearing of Turbid Solutions, by Professor Georg Quincke.

The Polarisation of Electric Waves, by Professor Georg Quincke.

Note sur l'unité de pression, par M. C. E. Guillaume.

Note on the Variation of the Specific Heat of Water, by Professor H. L. Callendar, F.R.S.

On the Behaviour of young Gulls artificially and naturally hatched, by Professor J. Arthur Thomson.

Synopsis of Grants of Money appropriated to Scientific Purposes by the General Committee at the Glasgow Meeting, September, 1901. The Names of the Members entitled to call on the General Treasurer for the respective Grants are prefixed.

Mathematics and Physics.

	£	s.	d.
*Rayleigh, Lord—Electrical Standards	40	0	0
*Judd, Professor J. W.—Seismological Observations	35	0	0
Shaw, Mr. W. N.—Investigation of the Upper Atmosphere by means of Kites	75	0	0
Preece, Sir W. H.—Magnetic Observations at Falmouth	80	0	0

Chemistry.

*Hartley, Professor W. N.—Relation between Absorption Spectra and Constitution of Organic Substances	20	0	0
*Roscoe, Sir H. E.—Wave-length Tables	5	0	0
Roberts-Austen, Sir Wm. C.—Properties of Metals and Alloys affected by dissolved Gases	40	0	0

Geology.

*Geikie, Professor J.—Photographs of Geological Interest	5	0	0
*Marr, Mr. J. E.—Life-zones in British Carboniferous Rocks	10	0	0
*Watts, Professor W. W.—Underground Water of North-west Yorkshire (Balance in hand)	—		
*Scharff, Dr.—Exploration of Irish Caves	45	0	0
*Woodward, Dr. H.—Type Specimens (Balance in hand)	—		

Zoology.

*Herdman, Professor W. A.—Table at the Zoological Station, Naples	100	0	0
*Garstang, Mr. W.—Table at the Biological Laboratory, Plymouth (Balance £8 5s. 0d. in hand)	—		
*Woodward, Dr. H.—Index Generum et Specierum Animalium	100	0	0
*Newton, Professor A.—Migration of Birds	15	0	0
*Sedgwick, Mr. A.—Structure of Coral Reefs of Indian Region	50	0	0
Murray, Sir John—Compound Ascidians of the Clyde Area	25	0	0

Geography.

*Keltie, Dr. J. Scott—Terrestrial Surface Waves	15	0	0

Economic Science and Statistics.

*Brabrook, E. W.—Legislation regulating Women's Labour	30	0	0

Engineering.

*Preece, Sir W. H.—Small Screw Gauge	20	0	0
*Binnie, Sir A.—Resistance of Road Vehicles to Traction	50	0	0
Carried forward	**£760**	**0**	**0**

* Reappointed.

	£	s.	d.
Brought forward	760	0	0
Anthropology.			
*Evans, Mr. A. J.—Silchester Excavation	5	0	0
*Penhallow, Professor D. P.—Ethnological Survey of Canada	15	0	0
*Garson, Dr. J. G.—Age of Stone Circles	30	0	0
*Read, Mr. C. H.—Photographs of Anthropological Interest (Balance in hand)	—		
*Tylor, Professor E. B.—Anthropological Teaching	3	0	0
*Evans, Sir John—Exploration in Crete	100	0	0
Macalister, Professor A.—Anthropometric Investigations on Native Egyptian Soldiers	15	0	0
Rhys, Professor J.—Excavations on the Roman Site at Gelligaer	5	0	0
Physiology.			
McKendrick, Professor J. G.—Work of Mammalian Heart under influence of Drugs	15	0	0
McKendrick, Professor J. G.—Changes in Hæmoglobin	20	0	0
Botany.			
Farmer, Professor J. B.—Investigations of the Cyanophyceæ	10	0	0
Marshall Ward, Professor—The Respiration of Plants	15	0	0
Educational Science.			
Armstrong, Dr. H. E.—Reciprocal Influence of Universities and Schools	5	0	0
Sherrington, Professor C. S.†—Conditions of Health essential to carrying on work in Schools	2	0	0
Corresponding Societies.			
*Whitaker, Mr. W.—Preparation of Report	15	0	0
	£1,015	0	0

* Reappointed. † Appointed by the Council.

The Annual Meeting in 1902.

The Annual Meeting of the Association in 1902 will be held at Belfast, commencing on September 10.

The Annual Meeting in 1903.

The Annual Meeting of the Association in 1903 will be held at Southport.

General Statement of Sums which have been paid on account of Grants for Scientific Purposes

1834.

	£	s.	d.
Tide Discussions	20	0	0

1835.

	£	s.	d.
Tide Discussions	62	0	0
British Fossil Ichthyology	105	0	0
	£167	0	0

1836.

	£	s.	d.
Tide Discussions	163	0	0
British Fossil Ichthyology	105	0	0
Thermometric Observations, &c.	50	0	0
Experiments on Long-continued Heat	17	1	0
Rain-gauges	9	13	0
Refraction Experiments	15	0	0
Lunar Nutation	60	0	0
Thermometers	15	6	0
	£435	0	0

1837.

	£	s.	d.
Tide Discussions	284	1	0
Chemical Constants	24	13	6
Lunar Nutation	70	0	0
Observations on Waves	100	12	0
Tides at Bristol	150	0	0
Meteorology and Subterranean Temperature	93	3	0
Vitrification Experiments	150	0	0
Heart Experiments	8	4	6
Barometric Observations	30	0	0
Barometers	11	18	6
	£922	12	6

1838.

	£	s.	d.
Tide Discussions	29	0	0
British Fossil Fishes	100	0	0
Meteorological Observations and Anemometer (construction)	100	0	0
Cast Iron (Strength of)	60	0	0
Animal and Vegetable Substances (Preservation of)	19	1	10
Railway Constants	41	12	10
Bristol Tides	50	0	0
Growth of Plants	75	0	0
Mud in Rivers	3	6	6
Education Committee	50	0	0
Heart Experiments	5	3	0
Land and Sea Level	267	8	7
Steam-vessels	100	0	0
Meteorological Committee	31	9	5
	£932	2	2

1839.

	£	s.	d.
Fossil Ichthyology	110	0	0
Meteorological Observations at Plymouth, &c.	63	10	0
Mechanism of Waves	144	2	0
Bristol Tides	35	18	6
Meteorology and Subterranean Temperature	21	11	0
Vitrification Experiments	9	4	0
Cast-iron Experiments	103	0	7
Railway Constants	28	7	0
Land and Sea Level	274	1	2
Steam-vessels' Engines	100	0	4
Stars in Histoire Céleste	171	18	0
Stars in Lacaille	11	0	6
Stars in R.A.S. Catalogue	166	16	0
Animal Secretions	10	10	6
Steam Engines in Cornwall	50	0	0
Atmospheric Air	16	1	0
Cast and Wrought Iron	40	0	0
Heat on Organic Bodies	3	0	0
Gases on Solar Spectrum	22	0	0
Hourly Meteorological Observations, Inverness and Kingussie	49	7	8
Fossil Reptiles	118	2	9
Mining Statistics	50	0	0
	£1595	11	0

1840.

	£	s.
Bristol Tides	100	0
Subterranean Temperature	13	13
Heart Experiments	18	19
Lungs Experiments	8	13
Tide Discussions	50	0
Land and Sea Level	6	11
Stars (Histoire Céleste)	242	10
Stars (Lacaille)	4	15
Stars (Catalogue)	264	0
Atmospheric Air	15	15
Water on Iron	10	0
Heat on Organic Bodies	7	0
Meteorological Observations	52	17
Foreign Scientific Memoirs	112	1
Working Population	100	0
School Statistics	50	0
Forms of Vessels	184	7
Chemical and Electrical Phenomena	40	0
Meteorological Observations at Plymouth	80	0
Magnetical Observations	185	13
	£1546	16

1841.

	£	s.	d.
Observations on Waves	30	0	0
Meteorology and Subterranean Temperature	8	8	0
Actinometers	10	0	0
Earthquake Shocks	17	7	0
Acrid Poisons.....................	6	0	0
Veins and Absorbents	3	0	0
Mud in Rivers	5	0	0
Marine Zoology	15	12	8
Skeleton Maps	20	0	0
Mountain Barometers	6	18	6
Stars (Histoire Céleste)	185	0	0
Stars (Lacaille)..................	79	5	0
Stars (Nomenclature of)	17	19	6
Stars (Catalogue of)	40	0	0
Water on Iron	50	0	0
Meteorological Observations at Inverness	20	0	0
Meteorological Observations (reduction of)	25	0	0
Fossil Reptiles	50	0	0
Foreign Memoirs	62	0	6
Railway Sections	38	1	0
Forms of Vessels	193	12	0
Meteorological Observations at Plymouth	55	0	0
Magnetical Observations......	61	18	8
Fishes of the Old Red Sandstone	100	0	0
Tides at Leith	50	0	0
Anemometer at Edinburgh ...	69	1	10
Tabulating Observations	9	6	3
Races of Men....................	5	0	0
Radiate Animals	2	0	0
	£1235	10	11

1842.

	£	s.	d.
Dynamometric Instruments..	113	11	2
Anoplura Britanniæ	52	12	0
Tides at Bristol	59	8	0
Gases on Light	30	14	7
Chronometers.....................	26	17	6
Marine Zoology.................	1	5	0
British Fossil Mammalia	100	0	0
Statistics of Education.........	20	0	0
Marine Steam-vessels' Engines	28	0	0
Stars (Histoire Céleste)	59	0	0
Stars (Brit. Assoc. Cat. of) ...	110	0	0
Railway Sections	161	10	0
British Belemnites	50	0	0
Fossil Reptiles (publication of Report)	210	0	0
Forms of Vessels	180	0	0
Galvanic Experiments on Rocks	5	8	6
Meteorological Experiments at Plymouth	68	0	0
Constant Indicator and Dynamometric Instruments	90	0	0
Force of Wind	10	0	0
Light on Growth of Seeds ...	8	0	0
Vital Statistics	50	0	0
Vegetative Power of Seeds ...	8	1	11
Questions on Human Race ...	7	9	0
	£1449	17	8

1843.

	£	s.	d.
Revision of the Nomenclature of Stars	2	0	
Reduction of Stars, British Association Catalogue	25	0	
Anomalous Tides, Firth of Forth	120	0	
Hourly Meteorological Observations at Kingussie and Inverness	77	12	
Meteorological Observations at Plymouth	55	0	
Whewell's Meteorological Anemometer at Plymouth	10	0	
Meteorological Observations Osler's Anemometer at Plymouth	20	0	
Reduction of Meteorological Observations	30	0	
Meteorological Instruments and Gratuities	39	6	0
Construction of Anemometer at Inverness	56	12	2
Magnetic Co-operation.........	10	8	10
Meteorological Recorder for Kew Observatory	50	0	0
Action of Gases on Light......	18	16	1
Establishment at Kew Observatory, Wages, Repairs, Furniture, and Sundries ...	133	4	7
Experiments by Captive Balloons	81	8	0
Oxidation of the Rails of Railways.......................	20	0	0
Publication of Report on Fossil Reptiles	40	0	0
Coloured Drawings of Railway Sections	147	18	3
Registration of Earthquake Shocks.........................	30	0	0
Report on Zoological Nomenclature.........................	10	0	0
Uncovering Lower Red Sandstone near Manchester	4	4	6
Vegetative Power of Seeds ...	5	3	8
Marine Testacea (Habits of) .	10	0	0
Marine Zoology	10	0	0
Marine Zoology	2	14	11
Preparation of Report on British Fossil Mammalia	100	0	0
Physiological Operations of Medicinal Agents	20	0	0
Vital Statistics	36	5	8

	£	s.	d.
Additional Experiments on the Forms of Vessels	70	0	0
Additional Experiments on the Forms of Vessels	100	0	0
Reduction of Experiments on the Forms of Vessels	100	0	0
Morin's Instrument and Constant Indicator	69	14	10
Experiments on the Strength of Materials	60	0	0
	£1565	10	2

1844.

	£	s.	d.
Meteorological Observations at Kingussie and Inverness	12	0	0
Completing Observations at Plymouth	35	0	0
Magnetic and Meteorological Co-operation	25	8	4
Publication of the British Association Catalogue of Stars	35	0	0
Observations on Tides on the East Coast of Scotland ...	100	0	0
Revision of the Nomenclature of Stars 1842	2	9	6
Maintaining the Establishment at Kew Observatory	117	17	3
Instruments for Kew Observatory	56	7	3
Influence of Light on Plants	10	0	0
Subterraneous Temperature in Ireland	5	0	0
Coloured Drawings of Railway Sections	15	17	6
Investigation of Fossil Fishes of the Lower Tertiary Strata	100	0	0
Registering the Shocks of Earthquakes 1842	23	11	10
Structure of Fossil Shells ...	20	0	0
Radiata and Mollusca of the Ægean and Red Seas 1842	100	0	0
Geographical Distributions of Marine Zoology.........1842	0	10	0
Marine Zoology of Devon and Cornwall	10	0	0
Marine Zoology of Corfu......	10	0	0
Experiments on the Vitality of Seeds	9	0	0
Experiments on the Vitality of Seeds 1842	8	7	
Exotic Anoplura	15	0	0
Strength of Materials	100	0	0
Completing Experiments on the Forms of Ships	100	0	0
Inquiries into Asphyxia	10	0	0
Investigations on the Internal Constitution of Metals......	50	0	0
Constant Indicator and Morin's Instrument 1842	10	0	0
	£981	12	

1845.

	£	s.	d.
Publication of the British Association Catalogue of Stars	351	14	6
Meteorological Observations at Inverness	30	18	11
Magnetic and Meteorological Co-operation	16	16	8
Meteorological Instruments at Edinburgh..................	18	11	9
Reduction of Anemometrical Observations at Plymouth	25	0	0
Electrical Experiments at Kew Observatory	43	17	8
Maintaining the Establishment at Kew Observatory	149	15	0
For Kreil's Barometrograph	25	0	0
Gases from Iron Furnaces...	50	0	0
The Actinograph	15	0	0
Microscopic Structure of Shells	20	0	0
Exotic Anoplura 1843	10	0	0
Vitality of Seeds 1843	2	0	7
Vitality of Seeds 1844	7	0	0
Marine Zoology of Cornwall .	10	0	0
Physiological Action of Medicines	20	0	0
Statistics of Sickness and Mortality in York..	20	0	0
Earthquake Shocks 1843	15	14	8
	£831	9	9

1846.

	£	s.	d.
British Association Catalogue of Stars 1844	211	15	0
Fossil Fishes of the London Clay............................	100	0	0
Computation of the Gaussian Constants for 1829	50	0	0
Maintaining the Establishment at Kew Observatory	146	16	7
Strength of Materials	60	0	0
Researches in Asphyxia	6	16	2
Examination of Fossil Shells	10	0	0
Vitality of Seeds 1844	2	15	10
Vitality of Seeds 1845	7	12	3
Marine Zoology of Cornwall	10	0	0
Marine Zoology of Britain ...	10	0	0
Exotic Anoplura 1844	25	0	0
Expenses attending Anemometers..........................	11	7	6
Anemometers' Repairs.........	2	3	6
Atmospheric Waves	3	3	3
Captive Balloons 1844	8	19	8
Varieties of the Human Race 1844	7	6	3
Statistics of Sickness and Mortality in York...........	12	0	0
	£685	16	0

1847.

	£	s.	d.
Computation of the Gaussian Constants for 1829	50	0	0
Habits of Marine Animals	10	0	0
Physiological Action of Medicines	20	0	0
Marine Zoology of Cornwall	10	0	0
Atmospheric Waves	6	9	3
Vitality of Seeds	4	7	7
Maintaining the Establishment at Kew Observatory	107	8	6
	£208	5	4

1848.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	171	15	11
Atmospheric Waves	3	10	9
Vitality of Seeds	9	15	0
Completion of Catalogue of Stars	70	0	0
On Colouring Matters	5	0	0
On Growth of Plants	15	0	0
	£275	1	8

1849.

	£	s.	d.
Electrical Observations at Kew Observatory	50	0	0
Maintaining the Establishment at ditto	76	2	5
Vitality of Seeds	5	8	1
On Growth of Plants	5	0	0
Registration of Periodical Phenomena	10	0	0
Bill on Account of Anemometrical Observations	13	9	0
	£159	19	6

1850.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	255	18	0
Transit of Earthquake Waves	50	0	0
Periodical Phenomena	15	0	0
Meteorological Instruments, Azores	25	0	0
	£345	18	0

1851.

	£	s.	d.
Maintaining the Establishment at Kew Observatory (includes part of grant in 1849)	309	2	2
Theory of Heat	20	1	1
Periodical Phenomena of Animals and Plants	5	0	0
Vitality of Seeds	5	6	4
Influence of Solar Radiation	30	0	0
Ethnological Inquiries	12	0	0
Researches on Annelida	10	0	0
	£391	9	7

1852.

	£	s.	d.
Maintaining the Establishment at Kew Observatory (including balance of grant for 1850)	233	17	
Experiments on the Conduction of Heat	5	2	9
Influence of Solar Radiations	20	0	0
Geological Map of Ireland	15	0	0
Researches on the British Annelida	10	0	0
Vitality of Seeds	10	6	2
Strength of Boiler Plates	10	0	0
	£304	6	7

1853.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	165	0	0
Experiments on the Influence of Solar Radiation	15	0	0
Researches on the British Annelida	10	0	0
Dredging on the East Coast of Scotland	10	0	0
Ethnological Queries	5	0	0
	£205	0	0

1854.

	£	s.	d.
Maintaining the Establishment at Kew Observatory (including balance of former grant)	330	15	4
Investigations on Flax	11	0	0
Effects of Temperature on Wrought Iron	10	0	0
Registration of Periodical Phenomena	10	0	0
British Annelida	10	0	0
Vitality of Seeds	5	2	3
Conduction of Heat	4	2	0
	£380	19	7

1855.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	425	0	0
Earthquake Movements	10	0	0
Physical Aspect of the Moon	11	8	5
Vitality of Seeds	10	7	11
Map of the World	15	0	0
Ethnological Queries	5	0	0
Dredging near Belfast	4	0	0
	£480	16	4

1856.

	£	s.	d.
Maintaining the Establishment at Kew Observatory:— 1854 .... £ 75 0 0; 1855 .... £500 0 0	575	0	0

	£	s.	d.
Strickland's Ornithological Synonyms	100	0	0
Dredging and Dredging Forms	9	13	0
Chemical Action of Light	20	0	0
Strength of Iron Plates	10	0	0
Registration of Periodical Phenomena	10	0	0
Propagation of Salmon	10	0	0
	£734	13	9

1857.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	350	0	0
Earthquake Wave Experiments	40	0	0
Dredging near Belfast	10	0	0
Dredging on the West Coast of Scotland	10	0	0
Investigations into the Mollusca of California	10	0	0
Experiments on Flax	5	0	0
Natural History of Madagascar	20	0	
Researches on British Annelida	25	0	0
Report on Natural Products imported into Liverpool	10	0	0
Artificial Propagation of Salmon	10	0	0
Temperature of Mines	7	8	0
Thermometers for Subterranean Observations	5	7	4
Life-boats	5	0	0
	£507	15	4

1858.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Earthquake Wave Experiments	25	0	0
Dredging on the West Coast of Scotland	10	0	0
Dredging near Dublin	5	0	0
Vitality of Seed	5	5	0
Dredging near Belfast	18	13	2
Report on the British Annelida	25	0	0
Experiments on the production of Heat by Motion in Fluids	20	0	0
Report on the Natural Products imported into Scotland	10	0	0
	£618	18	2

1859.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Dublin	15	0	0
Osteology of Birds	50	0	0
Irish Tunicata	5	0	0
Manure Experiments	20	0	0
British Medusidæ	5	0	0
Dredging Committee	5	0	0
Steam-vessels' Performance	5	0	0
Marine Fauna of South and West of Ireland	10	0	0
Photographic Chemistry	10	0	0
Lanarkshire Fossils	20	0	1
Balloon Ascents	39	11	0
	£684	11	1

1860.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Belfast	16	6	0
Dredging in Dublin Bay	15	0	0
Inquiry into the Performance of Steam-vessels	124	0	0
Explorations in the Yellow Sandstone of Dura Den	20	0	0
Chemico-mechanical Analysis of Rocks and Minerals	25	0	0
Researches on the Growth of Plants	10	0	0
Researches on the Solubility of Salts	30	0	0
Researches on the Constituents of Manures	25	0	0
Balance of Captive Balloon Accounts	1	13	6
	£766	19	

1861.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Earthquake Experiments	25	0	0
Dredging North and East Coasts of Scotland	23	0	0
Dredging Committee:— 1860......£50 0 0; 1861......£22 0 0	72	0	0
Excavations at Dura Den	20	0	0
Solubility of Salts	20	0	0
Steam-vessel Performance	150	0	0
Fossils of Lesmahagow	15	0	0
Explorations at Uriconium	20	0	0
Chemical Alloys	20	0	0
Classified Index to the Transactions	100	0	0
Dredging in the Mersey and Dee	5	0	0
Dip Circle	30	0	0
Photoheliographic Observations	50	0	0
Prison Diet	20	0	0
Gauging of Water	10	0	0
Alpine Ascents	6	5	10
Constituents of Manures	25	0	0
	£1111	5	10

1862.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Patent Laws	21	6	0
Mollusca of N.-W. of America	10	0	0
Natural History by Mercantile Marine	5	0	0
Tidal Observations	25	0	0
Photoheliometer at Kew	40	0	0
Photographic Pictures of the Sun	150	0	0
Rocks of Donegal	25	0	0
Dredging Durham and Northumberland Coasts	25	0	0
Connection of Storms	20	0	0
Dredging North-east Coast of Scotland	6	9	6
Ravages of Teredo	3	11	0
Standards of Electrical Resistance	50	0	0
Railway Accidents	10	0	0
Balloon Committee	200	0	0
Dredging Dublin Bay	10	0	0
Dredging the Mersey	5	0	0
Prison Diet	20	0	0
Gauging of Water	12	10	0
Steamships' Performance	150	0	0
Thermo-electric Currents	5	0	0
	£1293	16	6

1863.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Balloon Committee deficiency	70	0	0
Balloon Ascents (other expenses)	25	0	0
Entozoa	25	0	0
Coal Fossils	20	0	0
Herrings	20	0	0
Granites of Donegal	5	0	0
Prison Diet	20	0	0
Vertical Atmospheric Movements	13	0	0
Dredging Shetland	50	0	0
Dredging North-east Coast of Scotland	25	0	0
Dredging Northumberland and Durham	17	3	10
Dredging Committee superintendence	10	0	0
Steamship Performance	100	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Volcanic Temperature	100	0	0
Bromide of Ammonium	8	0	0
Electrical Standards	100	0	0
Electrical Construction and Distribution	40	0	0
Luminous Meteors	17	0	0
Kew Additional Buildings for Photoheliograph	100	0	0
Thermo-electricity	15	0	0
Analysis of Rocks	8	0	0
Hydroida	10	0	0
	£1608	3	10

1864.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Coal Fossils	20	0	0
Vertical Atmospheric Movements	20	0	0
Dredging, Shetland	75	0	0
Dredging, Northumberland	25	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Standards of Electric Resistance	100	0	0
Analysis of Rocks	10	0	0
Hydroida	10	0	0
Askham's Gift	50	0	0
Nitrite of Amyle	10	0	0
Nomenclature Committee	5	0	0
Rain-gauges	19	15	8
Cast-iron Investigation	20	0	0
Tidal Observations in the Humber	50	0	0
Spectral Rays	45	0	0
Luminous Meteors	20	0	0
	£1289	15	8

1865.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Balloon Committee	100	0	0
Hydroida	13	0	0
Rain-gauges	30	0	0
Tidal Observations in the Humber	6	8	0
Hexylic Compounds	20	0	0
Amyl Compounds	20	0	0
Irish Flora	25	0	0
American Mollusca	3	9	0
Organic Acids	20	0	0
Lingula Flags Excavation	10	0	0
Eurypterus	50	0	0
Electrical Standards	100	0	0
Malta Caves Researches	30	0	0
Oyster Breeding	25	0	0
Gibraltar Caves Researches	150	0	0
Kent's Hole Excavations	100	0	0
Moon's Surface Observations	35	0	0
Marine Fauna	25	0	0
Dredging Aberdeenshire	25	0	0
Dredging Channel Islands	50	0	0
Zoological Nomenclature	5	0	0
Resistance of Floating Bodies in Water	100	0	0
Bath Waters Analysis	8	10	10
Luminous Meteors	40	0	0
	£1591	7	10

1866.

	£	s.	d.
Maintaining the Establishment at Kew Observatory..	600	0	0
Lunar Committee...............	64	13	4
Balloon Committee	50	0	0
Metrical Committee............	50	0	0
British Rainfall..................	50	0	0
Kilkenny Coal Fields	16	0	0
Alum Bay Fossil Leaf-bed ...	15	0	0
Luminous Meteors	50	0	0
Lingula Flags Excavation ...	20	0	0
Chemical Constitution of Cast Iron	50	0	0
Amyl Compounds	25	0	0
Electrical Standards............	100	0	0
Malta Caves Exploration	30	0	0
Kent's Hole Exploration	200	0	0
Marine Fauna, &c., Devon and Cornwall	25	0	0
Dredging Aberdeenshire Coast	25	0	0
Dredging Hebrides Coast ...	50	0	0
Dredging the Mersey	5	0	0
Resistance of Floating Bodies in Water........................	50	0	0
Polycyanides of Organic Radicals	29	0	0
Rigor Mortis	10	0	0
Irish Annelida	15	0	0
Catalogue of Crania............	50	0	0
Didine Birds of Mascarene Islands	50	0	0
Typical Crania Researches ...	30	0	0
Palestine Exploration Fund...	100	0	0
	£1750	13	4

1867.

	£	s.	d.
Maintaining the Establishment at Kew Observatory..	600	0	0
Meteorological Instruments, Palestine........................	50	0	0
Lunar Committee	120	0	0
Metrical Committee............	30	0	0
Kent's Hole Explorations ...	100	0	0
Palestine Explorations.........	50	0	0
Insect Fauna, Palestine	30	0	0
British Rainfall..................	50	0	0
Kilkenny Coal Fields	25	0	0
Alum Bay Fossil Leaf-bed ...	25	0	0
Luminous Meteors	50	0	0
Bournemouth, &c., Leaf-beds	30	0	0
Dredging Shetland	75	0	0
Steamship Reports Condensation	100	0	0
Electrical Standards............	100	0	0
Ethyl and Methyl Series......	25	0	0
Fossil Crustacea	25	0	0
Sound under Water	24	4	0
North Greenland Fauna	75	0	0
Do. Plant Beds	100	0	0
Iron and Steel Manufacture...	25	0	0
Patent Laws	30	0	0
	£1739	4	0

1868.

	£	s.	d.
Maintaining the Establishment at Kew Observatory..	600	0	0
Lunar Committee	120	0	0
Metrical Committee...........	50	0	0
Zoological Record..............	100	0	0
Kent's Hole Explorations ..	150	0	0
Steamship Performances . ..	100	0	0
British Rainfall..................	50	0	0
Luminous Meteors..............	50	0	0
Organic Acids	60	0	0
Fossil Crustacea..................	25	0	0
Methyl Series......................	25	0	0
Mercury and Bile	25	0	0
Organic Remains in Limestone Rocks	25	0	0
Scottish Earthquakes	20	0	0
Fauna, Devon and Cornwall..	30	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-beds	50	0	0
Greenland Explorations	100	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature...	50	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Secondary Reptiles, &c.	30	0	0
British Marine Invertebrate Fauna	100	0	0
	£1940	0	0

1869.

	£	s.	d.
Maintaining the Establishment at Kew Observatory..	600	0	0
Lunar Committee	50	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Gases in Deep-well Water	25	0	0
British Rainfall.................	50	0	0
Thermal Conductivity of Iron, &c................................	30	0	0
Kent's Hole Explorations......	150	0	0
Steamship Performances	30	0	0
Chemical Constitution of Cast Iron........................	80	0	0
Iron and Steel Manufacture	100	0	0
Methyl Series....................	30	0	0
Organic Remains in Limestone Rocks................	10	0	0
Earthquakes in Scotland......	10	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-beds	30	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature...	30	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Organic Acids	12	0	0
Kiltorcan Fossils	20	0	0

	£	s.	d.
Chemical Constitution and Physiological Action Relations	15	0	0
Mountain Limestone Fossils	25	0	0
Utilisation of Sewage	10	0	0
Products of Digestion	10	0	0
	£1622	0	0

1870.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Marine Fauna	20	0	0
Ears in Fishes	10	0	0
Chemical Nature of Cast Iron	80	0	0
Luminous Meteors	30	0	0
Heat in the Blood	15	0	0
British Rainfall	100	0	0
Thermal Conductivity of Iron, &c.	20	0	0
British Fossil Corals	50	0	0
Kent's Hole Explorations	150	0	0
Scottish Earthquakes	4	0	0
Bagshot Leaf-beds	15	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Kiltorcan Quarries Fossils	20	0	0
Mountain Limestone Fossils	25	0	0
Utilisation of Sewage	50	0	0
Organic Chemical Compounds	30	0	0
Onny River Sediment	3	0	0
Mechanical Equivalent of Heat	50	0	0
	£1572	0	0

1871.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Monthly Reports of Progress in Chemistry	100	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Thermal Equivalents of the Oxides of Chlorine	10	0	0
Tidal Observations	100	0	0
Fossil Flora	25	0	0
Luminous Meteors	30	0	0
British Fossil Corals	25	0	0
Heat in the Blood	7	2	6
British Rainfall	50	0	0
Kent's Hole Explorations	150	0	0
Fossil Crustacea	25	0	0
Methyl Compounds	25	0	0
Lunar Objects	20	0	0
Fossil Coral Sections, for Photographing	20	0	0
Bagshot Leaf-beds	20	0	0
Moab Explorations	100	0	0
Gaussian Constants	40	0	0
	£1472	2	6

1872.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	300	0	0
Metrical Committee	75	0	0
Zoological Record	100	0	0
Tidal Committee	200	0	0
Carboniferous Corals	25	0	0
Organic Chemical Compounds	25	0	0
Exploration of Moab	100	0	0
Terato-embryological Inquiries	10	0	0
Kent's Cavern Exploration	100	0	0
Luminous Meteors	20	0	0
Heat in the Blood	15	0	0
Fossil Crustacea	25	0	0
Fossil Elephants of Malta	25	0	0
Lunar Objects	20	0	0
Inverse Wave-lengths	20	0	0
British Rainfall	100	0	0
Poisonous Substances Antagonism	10	0	0
Essential Oils, Chemical Constitution, &c.	40	0	0
Mathematical Tables	50	0	0
Thermal Conductivity of Metals	25	0	0
	£1285	0	0

1873.

	£	s.	d.
Zoological Record	100	0	0
Chemistry Record	200	0	0
Tidal Committee	400	0	0
Sewage Committee	100	0	0
Kent's Cavern Exploration	150	0	0
Carboniferous Corals	25	0	0
Fossil Elephants	25	0	0
Wave-lengths	150	0	0
British Rainfall	100	0	0
Essential Oils	30	0	0
Mathematical Tables	100	0	0
Gaussian Constants	10	0	0
Sub-Wealden Explorations	25	0	0
Underground Temperature	150	0	0
Settle Cave Exploration	50	0	0
Fossil Flora, Ireland	20	0	0
Timber Denudation and Rainfall	20	0	0
Luminous Meteors	30	0	0
	£1685	0	0

1874.

	£	s.	d.
Zoological Record	100	0	0
Chemistry Record	100	0	0
Mathematical Tables	100	0	0
Elliptic Functions	100	0	0
Lightning Conductors	10	0	0
Thermal Conductivity of Rocks	10	0	0
Anthropological Instructions	50	0	0
Kent's Cavern Exploration	150	0	0
Luminous Meteors	30	0	0
Intestinal Secretions	15	0	0
British Rainfall	100	0	0
Essential Oils	10	0	0
Sub-Wealden Explorations	25	0	0
Settle Cave Exploration	50	0	0
Mauritius Meteorology	100	0	0
Magnetisation of Iron	20	0	0
Marine Organisms	30	0	0
Fossils, North-West of Scotland	2	10	0
Physiological Action of Light	20	0	0
Trades Unions	25	0	0
Mountain Limestone-corals	25	0	0
Erratic Blocks	10	0	0
Dredging, Durham and Yorkshire Coasts	28	5	0
High Temperature of Bodies	30	0	0
Siemens's Pyrometer	3	6	0
Labyrinthodonts of Coal-measures	7	15	0
	£1151	16	0

1875.

	£	s.	d.
Elliptic Functions	100	0	0
Magnetisation of Iron	20	0	0
British Rainfall	120	0	0
Luminous Meteors	30	0	0
Chemistry Record	100	0	0
Specific Volume of Liquids	25	0	0
Estimation of Potash and Phosphoric Acid	10	0	0
Isometric Cresols	20	0	0
Sub-Wealden Explorations	100	0	0
Kent's Cavern Exploration	100	0	0
Settle Cave Exploration	50	0	0
Earthquakes in Scotland	15	0	0
Underground Waters	10	0	0
Development of Myxinoid Fishes	20	0	0
Zoological Record	100	0	0
Instructions for Travellers	20	0	0
Intestinal Secretions	20	0	0
Palestine Exploration	100	0	0
	£960	0	0

1876.

	£	s.	d.
Printing Mathematical Tables	159	4	2
British Rainfall	100	0	0
Ohm's Law	9	15	0
Tide Calculating Machine	200	0	0
Specific Volume of Liquids	25	0	0
Isomeric Cresols	10	0	0
Action of Ethyl Bromobutyrate on Ethyl Sodaceto-acetate	5	0	0
Estimation of Potash and Phosphoric Acid	13	0	0
Exploration of Victoria Cave	100	0	0
Geological Record	100	0	0
Kent's Cavern Exploration	100	0	0
Thermal Conductivities of Rocks	10	0	0
Underground Waters	10	0	0
Earthquakes in Scotland	1	10	0
Zoological Record	100	0	0
Close Time	5	0	0
Physiological Action of Sound	25	0	0
Naples Zoological Station	75	0	0
Intestinal Secretions	15	0	0
Physical Characters of Inhabitants of British Isles	13	15	0
Measuring Speed of Ships	10	0	0
Effect of Propeller on turning of Steam-vessels	5	0	0
	£1092	4	2

1877.

	£	s.	d.
Liquid Carbonic Acid in Minerals	20	0	0
Elliptic Functions	250	0	0
Thermal Conductivity of Rocks	9	11	7
Zoological Record	100	0	0
Kent's Cavern	100	0	0
Zoological Station at Naples	75	0	0
Luminous Meteors	30	0	0
Elasticity of Wires	100	0	0
Dipterocarpeæ, Report on	20	0	0
Mechanical Equivalent of Heat	35	0	0
Double Compounds of Cobalt and Nickel	8	0	0
Underground Temperature	50	0	0
Settle Cave Exploration	100	0	0
Underground Waters in New Red Sandstone	10	0	0
Action of Ethyl Bromobutyrate on Ethyl Sodaceto-acetate	10	0	0
British Earthworks	25	0	0
Atmospheric Electricity in India	15	0	0
Development of Light from Coal-gas	20	0	0
Estimation of Potash and Phosphoric Acid	1	18	0
Geological Record	100	0	0
Anthropometric Committee	34	0	0
Physiological Action of Phosphoric Acid, &c.	15	0	
	£1128	9	

1878.

	£	s.	d.
Exploration of Settle Caves	100	0	0
Geological Record	100	0	0
Investigation of Pulse Phenomena by means of Siphon Recorder	10	0	0
Zoological Station at Naples	75	0	0
Investigation of Underground Waters	15	0	0
Transmission of Electrical Impulses through Nerve Structure	30	0	0
Calculation of Factor Table for 4th Million	100	0	0
Anthropometric Committee	66	0	0
Composition and Structure of less-known Alkaloids	25	0	0
Exploration of Kent's Cavern	50	0	0
Zoological Record	100	0	0
Fermanagh Caves Exploration	15	0	0
Thermal Conductivity of Rocks	4	16	6
Luminous Meteors	10	0	0
Ancient Earthworks	25	0	0
	£725	16	6

	£	s.	d.
Specific Inductive Capacity of Sprengel Vacuum	40	0	0
Tables of Sun-heat Coefficients	30	0	0
Datum Level of the Ordnance Survey	10	0	0
Tables of Fundamental Invariants of Algebraic Forms	36	14	9
Atmospheric Electricity Observations in Madeira	15	0	0
Instrument for Detecting Fire-damp in Mines	22	0	0
Instruments for Measuring the Speed of Ships	17	1	8
Tidal Observations in the English Channel	10	0	0
	£1080	11	11

1879.

	£	s.	d.
Table at the Zoological Station, Naples	75	0	0
Miocene Flora of the Basalt of the North of Ireland	20	0	0
Illustrations for a Monograph on the Mammoth	17	0	0
Record of Zoological Literature	100	0	0
Composition and Structure of less-known Alkaloids	25	0	0
Exploration of Caves in Borneo	50	0	0
Kent's Cavern Exploration	100	0	0
Record of the Progress of Geology	100	0	0
Fermanagh Caves Exploration	5	0	0
Electrolysis of Metallic Solutions and Solutions of Compound Salts	25	0	0
Anthropometric Committee	50	0	0
Natural History of Socotra	100	0	0
Calculation of Factor Tables for 5th and 6th Millions	150	0	0
Underground Waters	10	0	0
Steering of Screw Steamers	10	0	0
Improvements in Astronomical Clocks	30	0	0
Marine Zoology of South Devon	20	0	0
Determination of Mechanical Equivalent of Heat	12	15	

1880.

	£	s.	d.
New Form of High Insulation Key	10	0	0
Underground Temperature	10	0	0
Determination of the Mechanical Equivalent of Heat	8	5	0
Elasticity of Wires	50	0	0
Luminous Meteors	30	0	0
Lunar Disturbance of Gravity	30	0	0
Fundamental Invariants	8	5	0
Laws of Water Friction	20	0	0
Specific Inductive Capacity of Sprengel Vacuum	20	0	0
Completion of Tables of Sun-heat Coefficients	50	0	0
Instrument for Detection of Fire-damp in Mines	10	0	0
Inductive Capacity of Crystals and Paraffines	4	17	
Report on Carboniferous Polyzoa	10	0	0
Caves of South Ireland	10	0	0
Viviparous Nature of Ichthyosaurus	10	0	0
Kent's Cavern Exploration	50	0	0
Geological Record	100	0	0
Miocene Flora of the Basalt of North Ireland	15	0	0
Underground Waters of Permian Formations	5	0	0
Record of Zoological Literature	100	0	0
Table at Zoological Station at Naples	75	0	0
Investigation of the Geology and Zoology of Mexico	50	0	0
Anthropometry	50	0	0
Patent Laws	5	0	0
	£731	7	7

1881.

	£	s.	d.
Lunar Disturbance of Gravity	30	0	0
Underground Temperature ...	20	0	0
Electrical Standards	25	0	0
High Insulation Key	5	0	0
Tidal Observations	10	0	0
Specific Refractions	7	3	1
Fossil Polyzoa	10	0	0
Underground Waters	10	0	0
Earthquakes in Japan	25	0	0
Tertiary Flora	20	0	0
Scottish Zoological Station ...	50	0	0
Naples Zoological Station ...	75	0	0
Natural History of Socotra ...	50	0	0
Anthropological Notes and Queries	9	0	0
Zoological Record	100	0	0
Weights and Heights of Human Beings	30	0	0
	£476	3	1

1882.

	£	s.	d.
Exploration of Central Africa	100	0	0
Fundamental Invariants of Algebraical Forms	76	1	11
Standards for Electrical Measurements	100	0	0
Calibration of Mercurial Thermometers	20	0	0
Wave-length Tables of Spectra of Elements	50	0	0
Photographing Ultra-violet Spark Spectra	25	0	0
Geological Record	100	0	0
Earthquake Phenomena of Japan	25	0	0
Conversion of Sedimentary Materials into Metamorphic Rocks	10		
Fossil Plants of Halifax	15		
Geological Map of Europe ...	25		
Circulation of Underground Waters	15	0	0
Tertiary Flora of North of Ireland	20	0	0
British Polyzoa	10	0	0
Exploration of Caves of South of Ireland	10	0	0
Exploration of Raygill Fissure	20	0	0
Naples Zoological Station ...	80	0	0
Albuminoid Substances of Serum	10	0	0
Elimination of Nitrogen by Bodily Exercise	50	0	0
Migration of Birds	15	0	0
Natural History of Socotra ...	100	0	0
Natural History of Timor-laut	100	0	0
Record of Zoological Literature	100	0	0
Anthropometric Committee...	50	0	0
	£1126	1	11

1883.

	£	s.	d.
Meteorological Observations on Ben Nevis	50	0	0
Isomeric Naphthalene Derivatives	15	0	0
Earthquake Phenomena of Japan	50	0	0
Fossil Plants of Halifax	20	0	0
British Fossil Polyzoa	10	0	0
Fossil Phyllopoda of Palæozoic Rocks	25	0	0
Erosion of Sea-coast of England and Wales	10	0	0
Circulation of Underground Waters	15	0	0
Geological Record	50	0	0
Exploration of Caves in South of Ireland	10	0	0
Zoological Literature Record	100	0	0
Migration of Birds	20	0	0
Zoological Station at Naples	80	0	0
Scottish Zoological Station...	25	0	0
Elimination of Nitrogen by Bodily Exercise	38	3	3
Exploration of Mount Kilima-njaro	500	0	0
Investigation of Loughton Camp	10	0	0
Natural History of Timor-laut	50	0	0
Screw Gauges	5	0	0
	£1083	3	3

1884.

	£	s.	d.
Meteorological Observations on Ben Nevis	50	0	0
Collecting and Investigating Meteoric Dust	20	0	0
Meteorological Observatory at Chepstow	25	0	0
Tidal Observations	10	0	0
Ultra Violet Spark Spectra ...	8	4	0
Earthquake Phenomena of Japan	75	0	0
Fossil Plants of Halifax	15	0	0
Fossil Polyzoa	10	0	0
Erratic Blocks of England ...	10	0	0
Fossil Phyllopoda of Palæozoic Rocks	15	0	0
Circulation of Underground Waters	5	0	0
International Geological Map	20	0	0
Bibliography of Groups of Invertebrata	50	0	0
Natural History of Timor-laut	50	0	0
Naples Zoological Station ...	80	0	0
Exploration of Mount Kilima-njaro, East Africa	500	0	0
Migration of Birds	20	0	0
Coagulation of Blood	100	0	0
Zoological Literature Record	100	0	0
Anthropometric Committee...	10	0	0
	£1173	4	0

1885.

	£	s.	d.
Synoptic Chart of Indian Ocean	50	0	0
Reduction of Tidal Observations	10	0	0
Calculating Tables in Theory of Numbers	100	0	0
Meteorological Observations on Ben Nevis	50	0	0
Meteoric Dust	70	0	0
Vapour Pressures, &c., of Salt Solutions	25	0	0
Physical Constants of Solutions	20	0	0
Volcanic Phenomena of Vesuvius	25	0	0
Raygill Fissure	15	0	0
Earthquake Phenomena of Japan	70	0	0
Fossil Phyllopoda of Palæozoic Rocks	25	0	0
Fossil Plants of British Tertiary and Secondary Beds	50	0	0
Geological Record	50	0	0
Circulation of Underground Waters	10	0	0
Naples Zoological Station	100	0	0
Zoological Literature Record	100	0	0
Migration of Birds	30	0	0
Exploration of Mount Kilima-njaro	25	0	0
Recent Polyzoa	10	0	0
Granton Biological Station	100	0	0
Biological Stations on Coasts of United Kingdom	150	0	0
Exploration of New Guinea	200	0	0
Exploration of Mount Roraima	100	0	0
	£1385	[illegible]	0

1886.

	£	s.	d.
Electrical Standards	40	0	0
Solar Radiation	9	10	6
Tidal Observations	50	0	0
Magnetic Observations	10	10	0
Observations on Ben Nevis	100	0	0
Physical and Chemical Bearings of Electrolysis	20	0	0
Chemical Nomenclature	5	0	0
Fossil Plants of British Tertiary and Secondary Beds	20	0	0
Caves in North Wales	25	0	0
Volcanic Phenomena of Vesuvius	30	0	0
Geological Record	100	0	0
Palæozoic Phyllopoda	15	0	0
Zoological Literature Record	100	0	0
Granton Biological Station	75	0	0
Naples Zoological Station	50	0	0
Researches in Food-Fishes and Invertebrata at St. Andrews	75	0	0
Migration of Birds	30	0	0
Secretion of Urine	10	0	0
Exploration of New Guinea	150	0	0
Regulation of Wages under Sliding Scales	10	0	0
Prehistoric Race in Greek Islands	20	0	0
North-Western Tribes of Canada	50	0	0
	£995	0	6

1887.

	£	s.	d.
Solar Radiation	18	10	0
Electrolysis	30	0	0
Ben Nevis Observatory	75	0	0
Standards of Light (1886 grant)	20	0	
Standards of Light (1887 grant)	10	0	
Harmonic Analysis of Tidal Observations	15	0	0
Magnetic Observations	26	2	0
Electrical Standards	50	0	0
Silent Discharge of Electricity	20	0	0
Absorption Spectra	40	0	0
Nature of Solution	20	0	0
Influence of Silicon on Steel	30	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Volcanic Phenomena of Japan (1886 grant)	50	0	0
Volcanic Phenomena of Japan (1887 grant)	50	0	0
Cae Gwyn Cave, N. Wales	20	0	0
Erratic Blocks	10	0	0
Fossil Phyllopoda	20	0	0
Coal Plants of Halifax	25	0	0
Microscopic Structure of the Rocks of Anglesey	10	0	0
Exploration of the Eocene Beds of the Isle of Wight	20	0	0
Underground Waters	5	0	0
'Manure' Gravels of Wexford	10	0	0
Provincial Museums Reports	5	0	0
Lymphatic System	25	0	0
Naples Biological Station	100	0	0
Plymouth Biological Station	50	0	0
Granton Biological Station	75	0	0
Zoological Record	100	0	0
Flora of China	75	0	0
Flora and Fauna of the Cameroons	75	0	0
Migration of Birds	30	0	0
Bathy-hypsographical Map of British Isles	7	6	0
Regulation of Wages	10	0	0
Prehistoric Race of Greek Islands	20	0	0
Racial Photographs, Egyptian	20	0	0
	£1186	18	0

1888.

	£	s.	d.
Ben Nevis Observatory	150	0	0
Electrical Standards	2	6	4
Magnetic Observations	15	0	0
Standards of Light	79	2	3
Electrolysis	30	0	0
Uniform Nomenclature in Mechanics	10	0	0
Silent Discharge of Electricity	9	11	10
Properties of Solutions	25	0	0
Influence of Silicon on Steel	20	0	0
Methods of Teaching Chemistry	10	0	0
Isomeric Naphthalene Derivatives	25	0	0
Action of Light on Hydracids	20	0	0
Sea Beach near Bridlington	20	0	0
Geological Record	50	0	0
Manure Gravels of Wexford	10	0	0
Erosion of Sea Coasts	10	0	0
Underground Waters	5	0	0
Palæontographical Society	50	0	0
Pliocene Fauna of St. Erth	50	0	0
Carboniferous Flora of Lancashire and West Yorkshire	25	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Zoology and Botany of West Indies	100	0	0
Flora of Bahamas	100	0	0
Development of Fishes—St. Andrews	50	0	0
Marine Laboratory, Plymouth	100	0	0
Migration of Birds	30	0	0
Flora of China	75	0	0
Naples Zoological Station	100	0	0
Lymphatic System	25	0	0
Biological Station at Granton	50	0	0
Peradeniya Botanical Station	50	0	0
Development of Teleostei	15	0	0
Depth of Frozen Soil in Polar Regions	5	0	0
Precious Metals in Circulation	20	0	0
Value of Monetary Standard	10	0	0
Effect of Occupations on Physical Development	25	0	0
North-Western Tribes of Canada	100	0	0
Prehistoric Race in Greek Islands	20	0	0
	£1511	0	5

1889.

	£	s.	d.
Ben Nevis Observatory	50	0	0
Electrical Standards	75	0	0
Electrolysis	20	0	0
Surface Water Temperature	30	0	0
Silent Discharge of Electricity on Oxygen	6	4	8
Methods of teaching Chemistry	10	0	0
Action of Light on Hydracids	10	0	0
Geological Record	80	0	0
Volcanic Phenomena of Japan	25	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Palæozoic Phyllopoda	20	0	0
Higher Eocene Beds of Isle of Wight	15	0	0
West Indian Explorations	100	0	0
Flora of China	25	0	0
Naples Zoological Station	100	0	0
Physiology of Lymphatic System	25	0	0
Experiments with a Tow-net	5	16	3
Natural History of Friendly Islands	100	0	0
Geology and Geography of Atlas Range	100	0	0
Action of Waves and Currents in Estuaries	100	0	0
North-Western Tribes of Canada	150	0	0
Nomad Tribes of Asia Minor	30	0	0
Corresponding Societies	20	0	0
Marine Biological Association	200	0	0
'Baths Committee,' Bath	100	0	0
	£1417	0	11

1890.

	£	s.	d.
Electrical Standards	12	17	0
Electrolysis	5	0	0
Electro-optics	50	0	0
Mathematical Tables	25	0	0
Volcanic and Seismological Phenomena of Japan	75	0	0
Pellian Equation Tables	15	0	0
Properties of Solutions	10	0	0
International Standard for the Analysis of Iron and Steel	10	0	0
Influence of the Silent Discharge of Electricity on Oxygen	5	0	0
Methods of teaching Chemistry	10	0	0
Recording Results of Water Analysis	4	1	0
Oxidation of Hydracids in Sunlight	15	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Palæozoic Phyllopoda	10	0	0
Circulation of Underground Waters	5	0	0
Excavations at Oldbury Hill	15	0	0
Cretaceous Polyzoa	10	0	0
Geological Photographs	7	11	11
Lias Beds of Northampton	25	0	0
Botanical Station at Peradeniya	25	0	0

	£	s.	d.
Experiments with a Tow-net	4	3	9
Naples Zoological Station	100	0	0
Zoology and Botany of the West India Islands	100	0	0
Marine Biological Association	30	0	0
Action of Waves and Currents in Estuaries	150	0	0
Graphic Methods in Mechanical Science	11	0	0
Anthropometric Calculations	5	0	0
Nomad Tribes of Asia Minor	25	0	0
Corresponding Societies	20	0	0
	£799	16	8

1891.

	£	s.	d.
Ben Nevis Observatory	50	0	0
Electrical Standards	100	0	0
Electrolysis	5	0	0
Seismological Phenomena of Japan	10	0	0
Temperatures of Lakes	20	0	0
Photographs of Meteorological Phenomena	5	0	0
Discharge of Electricity from Points	10	0	0
Ultra Violet Rays of Solar Spectrum	50	0	0
International Standard for Analysis of Iron and Steel	10	0	0
Isomeric Naphthalene Derivatives	25	0	0
Formation of Haloids	25	0	0
Action of Light on Dyes	17	10	0
Geological Record	100	0	0
Volcanic Phenomena of Vesuvius	10	0	0
Fossil Phyllopoda	10	0	0
Photographs of Geological Interest	9	5	0
Lias of Northamptonshire	25	0	0
Registration of Type-Specimens of British Fossils	5	5	0
Investigation of Elbolton Cave	25	0	0
Botanical Station at Peradeniya	50	0	0
Experiments with a Tow-net	40	0	0
Marine Biological Association	12	10	0
Disappearance of Native Plants	5	0	0
Action of Waves and Currents in Estuaries	125	0	0
Anthropometric Calculations	10	0	0
New Edition of 'Anthropological Notes and Queries'	50	0	0
North - Western Tribes of Canada	200	0	0
Corresponding Societies	25	0	0
	£1,029	10	0

1892.

	£	s.	d.
Observations on Ben Nevis	50	0	0
Photographs of Meteorological Phenomena	15	0	0
Pellian Equation Tables	10	0	0
Discharge of Electricity from Points	50	0	0
Seismological Phenomena of Japan	10	0	0
Formation of Haloids	12	0	0
Properties of Solutions	10	0	0
Action of Light on Dyed Colours	10	0	0
Erratic Blocks	15	0	0
Photographs of Geological Interest	20	0	0
Underground Waters	10	0	0
Investigation of Elbolton Cave	25	0	0
Excavations at Oldbury Hill	10	0	0
Cretaceous Polyzoa	10	0	0
Naples Zoological Station	100	0	0
Marine Biological Association	17	10	0
Deep-sea Tow-net	40	0	0
Fauna of Sandwich Islands	100	0	0
Zoology and Botany of West India Islands	100	0	0
Climatology and Hydrography of Tropical Africa	50	0	0
Anthropometric Laboratory	5	0	0
Anthropological Notes and Queries	20	0	0
Prehistoric Remains in Mashonaland	50	0	0
North - Western Tribes of Canada	100	0	0
Corresponding Societies	25	0	0
	£864	10	0

1893.

	£	s.	d.
Electrical Standards	25	0	0
Observations on Ben Nevis	150	0	0
Mathematical Tables	15	0	0
Intensity of Solar Radiation	2	8	6
Magnetic Work at the Falmouth Observatory	25	0	0
Isomeric Naphthalene Derivatives	20	0	0
Erratic Blocks	10	0	0
Fossil Phyllopoda	5	0	0
Underground Waters	5	0	0
Shell-bearing Deposits at Clava, Chapelhall, &c.	20	0	0
Eurypterids of the Pentland Hills	10	0	0
Naples Zoological Station	100	0	0
Marine Biological Association	30	0	0
Fauna of Sandwich Islands	100	0	0
Zoology and Botany of West India Islands	50	0	0

	£	s.	d.
Exploration of Irish Sea	30	0	0
Physiological Action of Oxygen in Asphyxia	20	0	0
Index of Genera and Species of Animals	20	0	0
Exploration of Karakoram Mountains	50	0	0
Scottish Place-names	7	0	0
Climatology and Hydrography of Tropical Africa	50	0	0
Economic Training	3	7	0
Anthropometric Laboratory	5	0	0
Exploration in Abyssinia	25	0	0
North-Western Tribes of Canada	100	0	0
Corresponding Societies	30	0	0
	£907	15	6

1894.

	£	s.	d.
Electrical Standards............	25	0	0
Photographs of Meteorological Phenomena.......................	10	0	0
Tables of Mathematical Functions	15	0	0
Intensity of Solar Radiation	5	5	6
Wave-length Tables	10	0	0
Action of Light upon Dyed Colours	5	0	0
Erratic Blocks	15	0	0
Fossil Phyllopoda	5	0	0
Shell-bearing Deposits at Clava, &c.	20	0	0
Eurypterids of the Pentland Hills............................	5	0	0
New Sections of Stonesfield Slate	14	0	0
Observations on Earth-tremors	50	0	0
Exploration of Calf-Hole Cave............................	5	0	0
Naples Zoological Station ...	100	0	0
Marine Biological Association	5	0	0
Zoology of the Sandwich Islands	100	0	0
Zoology of the Irish Sea	40	0	0
Structure and Function of the Mammalian Heart............	10	0	0
Exploration in Abyssinia ...	30	0	0
Economic Training	9	10	0
Anthropometric Laboratory Statistics.......................	5	0	0
Ethnographical Survey	10	0	0
The Lake Village at Glastonbury............................	40	0	0
Anthropometrical Measurements in Schools	5	0	0
Mental and Physical Condition of Children..............	20	0	0
Corresponding Societies	25	0	0
	£583	15	6

1895.

	£	s.	d.
Electrical Standards............	25	0	0
Photographs of Meteorological Phenomena......................	10	0	0
Earth Tremors	75	0	0
Abstracts of Physical Papers	100	0	0
Reduction of Magnetic Observations made at Falmouth Observatory	50	0	0
Comparison of Magnetic Standards	25	0	0
Meteorological Observations on Ben Nevis	50	0	0
Wave-length Tables of the Spectra of the Elements ...	10	0	0
Action of Light upon Dyed Colours	4	6	1
Formation of Haloids from Pure Materials	20	0	0
Isomeric Naphthalene Derivatives............................	30	0	0
Electrolytic Quantitative Analysis	30	0	0
Erratic Blocks	10	0	0
Palæozoic Phyllopoda	5	0	0
Photographs of Geological Interest	10	0	0
Shell-bearing Deposits at Clava, &c.	10	0	0
Eurypterids of the Pentland Hills............................	3	0	
New Sections of Stonesfield Slate	50	0	
Exploration of Calf Hole Cave	10	0	
Nature and Probable Age of High-level Flint-drifts	10	0	
Table at the Zoological Station at Naples	100	0	
Table at the Biological Laboratory, Plymouth	15	0	
Zoology, Botany, and Geology of the Irish Sea...............	35	9	
Zoology and Botany of the West India Islands	50	0	
Index of Genera and Species of Animals	50	0	
Climatology of Tropical Africa	5	0	
Exploration of Hadramut ...	50	0	
Calibration and Comparison of Measuring Instruments ...	25	0	
Anthropometric Measurements in Schools	5	0	
Lake Village at Glastonbury	30	0	
Exploration of a Kitchen-midden at Hastings	10	0	
Ethnographical Survey	10	0	
Physiological Applications of the Phonograph...............	25	0	
Corresponding Societies	30	0	
	£977	15	

1896.

	£	s.	d.
Photographs of Meteorological Phenomena	15	0	0
Seismological Observations...	80	0	0
Abstracts of Physical Papers	100	0	0
Calculation of Certain Integrals	10	0	0
Uniformity of Size of Pages of Transactions, &c.	5	0	0
Wave-length Tables of the Spectra of the Elements ...	10	0	0
Action of Light upon Dyed Colours	2		1
Electrolytic Quantitative Analysis	10	0	0
The Carbohydrates of Barley Straw	50	0	0
Reprinting Discussion on the Relation of Agriculture to Science	5	0	0
Erratic Blocks	10	0	0
Palæozoic Phyllopoda	5	0	0
Shell-bearing Deposits at Clava, &c.	10	0	0
Eurypterids of the Pentland Hills	2	0	0
Investigation of a Coral Reef by Boring and Sounding ...	10	0	0
Examination of Locality where the Cetiosaurus in the Oxford Museum was found ...	25	0	0
Palæolithic Deposits at Hoxne	25	0	0
Fauna of Singapore Caves ...	40	0	0
Age and Relation of Rocks near Moreseat, Aberdeen .	10	0	0
Table at the Zoological Station at Naples	100	0	0
Table at the Biological Laboratory, Plymouth	15	0	0
Zoology, Botany, and Geology of the Irish Sea	50	0	0
Zoology of the Sandwich Islands	100	0	0
African Lake Fauna	100	0	0
Oysters under Normal and Abnormal Environment ...	40	0	0
Climatology of Tropical Africa	10	0	0
Calibration and Comparison of Measuring Instruments	20	0	0
Small Screw Gauge	10	0	0
North-Western Tribes of Canada	100	0	0
Lake Village at Glastonbury.	30	0	0
Ethnographical Survey	40	0	0
Mental and Physical Condition of Children	10	0	0
Physiological Applications of the Phonograph	25	0	0
Corresponding Societies Committee	30	0	0
	£1,104	6	1

1897.

	£	s.	d.
Mathematical Tables	25	0	0
Seismological Observations...	100	0	0
Abstracts of Physical Papers	100	0	0
Calculation of Certain Integrals	10	0	0
Electrolysis and Electrochemistry	50	0	0
Electrolytic Quantitative Analysis	10	0	0
Isomeric Naphthalene Derivatives	50	0	0
Erratic Blocks	10	0	0
Photographs of Geological Interest	15	0	0
Remains of the Irish Elk in the Isle of Man	15	0	0
Table at the Zoological Station, Naples	100	0	0
Table at the Biological Laboratory, Plymouth	9	10	8
Zoological Bibliography and Publication	5	0	0
Index Generum et Specierum Animalium	100	0	0
Zoology and Botany of the West India Islands	40	0	0
The Details of Observations on the Migration of Birds	40	0	0
Climatology of Tropical Africa	20	0	0
Ethnographical Survey	40	0	0
Mental and Physical Condition of Children	10	0	0
Silchester Excavation	20	0	0
Investigation of Changes associated with the Functional Activity of Nerve Cells and their Peripheral Extensions	180	0	0
Oysters and Typhoid	30	0	0
Physiological Applications of the Phonograph	15	0	0
Physiological Effects of Peptone and its Precursors	20	0	0
Fertilisation in Phæophyceæ	20	0	0
Corresponding Societies Committee	25	0	0
	£1,059	10	8

1898.

	£	s.	d.
Electrical Standards	75	0	0
Seismological Observations...	75	0	0
Abstracts of Physical Papers	100	0	0
Calculation of Certain Integrals	10	0	0
Electrolysis and Electro-chemistry	35	0	0
Meteorological Observatory at Montreal	50	0	0

	£	s.	d.
Wave-length Tables of the Spectra of the Elements ...	20	0	0
Action of Light upon Dyed Colours ...	8	0	0
Erratic Blocks ...	5	0	0
Investigation of a Coral Reef	40	0	0
Photographs of Geological Interest ...	10	0	0
Life-zones in British Carboniferous Rocks...	15	0	0
Pleistocene Fauna and Flora in Canada ...	20	0	
Table at the Zoological Station, Naples ...	100	0	
Table at the Biological Laboratory, Plymouth ...	14	0	
Index Generum et Specierum Animalium ...	100	0	
Healthy and Unhealthy Oysters ...	30	0	0
Climatology of Tropical Africa	10	0	0
State Monopolies in other Countries ...	15	0	0
Small Screw Gauge ...	20	0	0
North-Western Tribes of Canada...	75	0	0
Lake Village at Glastonbury	37	10	0
Silchester Excavation ...	7	10	0
Ethnological Survey of Canada	75	0	0
Anthropology and Natural History of Torres Straits...	125	0	0
Investigation of Changes associated with the Functional Activity of Nerve Cells and their Peripheral Extensions	100	0	0
Fertilisation in Phæophyceæ	15	0	0
Corresponding Societies Committee ...	25	0	0
	£1,212	0	0

1899.

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General Meetings.

On Wednesday, September 11, at 8.30 P.M., in St. Andrew's Hall, Glasgow, Sir William Turner, K.C.B., F.R.S., resigned the office of President to Professor A. W. Rücker, D.Sc., Sec. R.S., F.R.S., who took the Chair, and delivered an Address, for which see page 3.

On Thursday, September 12, at 8.30 P.M., a Soirée took place in the City Chambers.

On Friday, September 13, at 8.30 P.M., in St. Andrew's Hall, Professor W. Ramsay, F.R.S., delivered a Discourse on 'The Inert Constituents of the Atmosphere.'

On Monday, September 16, at 8.30 P.M., in St. Andrew's Hall, Mr. Francis Darwin, F.R.S., delivered a Discourse on 'The Movements of Plants.'

On Tuesday, September 17, at 8.30 P.M., a Soirée took place in the Exhibition Buildings.

On Wednesday, September 18, at 2.30 P.M., in the University, the concluding General Meeting took place, when the Proceedings of the General Committee and the Grants of Money for Scientific Purposes were explained to the Members.

The Meeting was then adjourned to Belfast. [The Meeting is appointed to commence on Wednesday, September 10, 1902.]

PRESIDENT'S ADDRESS.

ADDRESS

BY

Professor ARTHUR W. RÜCKER, M.A., LL.D., D.Sc., Sec.R.S.

PRESIDENT.

The first thought in the minds of all of us to-night is that since we met last year the great Queen, in whose reign nearly all the meetings of the British Association have been held, has passed to her rest.

To Sovereigns most honours and dignities come as of right; but for some of them is reserved the supreme honour of an old age softened by the love and benedictions of millions; of a path to the grave, not only magnificent, but watered by the tears both of their nearest and dearest, and of those who, at the most, have only seen them from afar.

This honour Queen Victoria won. All the world knows by what great abilities, by what patient labour, by what infinite tact and kindliness, the late Queen gained both the respect of the rulers of nations and the affection of her own subjects.

Her reign, glorious in many respects, was remarkable, outside these islands, for the growth of the Empire; within and without them, for the drawing nearer of the Crown and the people in mutual trust; while, during her lifetime, the developments of science and of scientific industry have altered the habits and the thoughts of the whole civilised world.

The representatives of science have already expressed in more formal ways their sorrow at the death of Queen Victoria, and the loyalty and confident hope for the future with which they welcome the accession of King Edward. But none the less, I feel sure that at this, the first meeting of the British Association held in his reign, I am only expressing the universal opinion of all our members when I say that no group of the King's subjects trusts more implicitly than we do in the ability, skill, and judgment which His Majesty has already shown in the exercise of the powers and duties of his august office; that none sympathise more deeply with the sorrows which two great nations have shared with their Sovereigns; and that none cry with more fervour, 'Long live the King!'

But this Meeting of the British Association is not only remarkable as being the first in a new reign. It is also the first in a new century.

It is held in Glasgow at a time when your International Exhibition has in a special sense attracted the attention of the world to your city, and when the recent celebration of the ninth jubilee of your University has shown how deeply the prosperity of the present is rooted in the past. What wonder, then, if I take the Chair to which you have called me with some misgivings? Born and bred in the South, I am to preside over a Meeting held in the largest city of Scotland. As your chosen mouthpiece I am to speak to you of science when we stand at the parting of the centuries, and when the achievements of the past and present, and the promise of the future, demand an interpreter with gifts of knowledge and divination to which I cannot pretend. *Lastly*, I am President of the British Association as a disciple in the home of the master, as a physicist in a city which a physicist has made for ever famous. Whatever the future may have in store for Glasgow, whether your enterprise is still to add wharf to wharf, factory to factory, and street to street, or whether some unforeseen 'tide in the affairs of men' is to sweep energy and success elsewhere, fifty-three years in the history of your city will never be forgotten while civilisation lasts.

More than half a century ago, a mere lad was the first to compel the British Association to listen to the teaching of Joule, and to accept the law of the conservation of energy. Now, alike in the most difficult mathematics and in the conception of the most ingenious apparatus, in the daring of his speculations and in the soundness of his engineering, William Thomson, Lord Kelvin, is regarded as a leader by the science and industry of the whole world.

It is the less necessary to dwell at length upon all that he has done, for Lord Kelvin has not been without honour in his own country. Many of us, who meet here to-night, met last in Glasgow when the University and City had invited representatives of all nations to celebrate the Jubilee of his professorship. For those two or three days learning was surrounded with a pomp seldom to be seen outside a palace. The strange middle-age costumes of all the chief Universities of the world were jostling here, the outward signs that those who were themselves distinguished in the study of Nature had gathered to do honour to one of the most distinguished of them all.

Lord Kelvin's achievements were then described in addresses in every tongue, and therefore I will only remind you that we, assembled here to-night, owe him a heavy debt of gratitude; for the fact that the British Association enters on the twentieth century conscious of a work to do and of the vigour to do it is largely due to his constant presence at its Meetings and to the support he has so ungrudgingly given. We have learned to know not only the work of our great leader, but the man himself; and I count myself happy because in his life-long home, under the walls of the University he served so well, and at a Meeting of the Association which his genius has so often illuminated, I am allowed, as your President, to assure him in your name of the admiration, respect, nay, affection, in which we all hold him.

I have already mentioned a number of circumstances which make our Meeting this year noteworthy; to these I must add that for the first time we have a Section for Education, and the importance of this new departure, due largely to the energy of Professor Armstrong, is emphasised by the fact that the Chair of that Section will be occupied by the Vice-President of the Board of Education—Sir John Gorst. I will not attempt to forecast the proceedings of the new Section. Education is passing through a transitional stage. The recent debates in Parliament; the great gifts of Mr. Carnegie; the discussion as to University organisation in the North of England; the reconstitution of the University of London; the increasing importance attached to the application of knowledge both to the investigation of Nature and to the purposes of industry, are all evidence of the growing conviction that without advance in education we cannot retain our position among the nations of the world. If the British Association can provide a platform on which these matters may be discussed in a scientific but practical spirit, free from the misrepresentations of the hustings and the exaggerations of the partisan, it will contribute in no slight measure to the national welfare.

But amid the old and new activities of our meeting the undertone of sadness, which is never absent from such gatherings, will be painfully apparent to many of us at Glasgow. Our sympathy goes out to the sister nation across the sea, which is watching by the sick-bed on which the President of the United States has been stretched by a coward hand. You will, I am sure, be glad to hear that the General Committee has already telegraphed, in the name of the Association, to President McKinley assuring him of their earnest hopes for his speedy and complete recovery. Nearer home the life-work of Professor Tait has ended amid the gloom of the war-cloud. A bullet, fired thousands of miles away, struck him to the heart, so that in their deaths the father and the brave son, whom he loved so well, were not long divided. Within the last year, too, America has lost Rowland; Viriamu Jones, who did yeoman's service for education and for science, has succumbed to a long and painful illness; and one who last year at Bradford seconded the proposal that I should be your President at Glasgow, and who would unquestionably have occupied this Chair before long had he been spared to do so, has unexpectedly been called away. A few months ago we had no reason to doubt that George Francis FitzGerald had many years of health and work before him. He had gained in a remarkable way not only the admiration of the scientific world, but the affection of his friends, and we shall miss sadly one whom we all cared for, and who, we hoped, might yet add largely to the achievements which had made him famous.

The Science of the Nineteenth Century.

Turning from these sad thoughts to the retrospect of the century which has so lately ended, I have found it to be impossible to free myself

from the influence of the moment and to avoid, even if it were desirable to avoid, the inclination to look backward from the standpoint of to-day.

Two years ago Sir Michael Foster dealt with the work of the century as a whole. Last year Sir William Turner discussed in greater detail the growth of a single branch of science. A third and humbler task remains, viz., to fix our attention on some of the hypotheses and assumptions on which the fabric of modern theoretical science has been built, and to inquire whether the foundations have been so 'well and truly' laid that they may be trusted to sustain the mighty superstructure which is being raised upon them.

The moment is opportune. The three chief conceptions which for many years have dominated physical as distinct from biological science have been the theories of the existence of atoms, of the mechanical nature of heat, and of the existence of the ether.

Dalton's atomic theory was first given to the world by a Glasgow professor—Thomas Thomson—in the year 1807, Dalton having communicated it to him in 1804. Rumford's and Davy's experiments on the nature of heat were published in 1798 and 1799 respectively; and the celebrated Bakerian Lecture, in which Thomas Young established the undulatory theory by explaining the interference of light, appeared in the 'Philosophical Transactions' in 1801. The keynotes of the physical science of the nineteenth century were thus struck, as the century began, by four of our fellow-countrymen, one of whom—Sir Benjamin Thompson, Count Rumford—preferred exile from the land of his birth to the loss of his birthright as a British citizen.

Doubts as to Scientific Theories.

It is well known that of late doubts have arisen as to whether the atomic theory, with which the mechanical theory of heat is closely bound up, and the theory of the existence of an ether have not served their purpose, and whether the time has not come to reconsider them.

The facts that Professor Poincaré, addressing a congress of physicists in Paris, and Professor Poynting, addressing the Physical Section of the Association, have recently discussed the true meaning of our scientific methods of interpretation; that Dr. James Ward has lately delivered an attack of great power on many positions which eminent scientific men have occupied; and that the approaching end of the nineteenth century led Professor Hæckel to define in a more popular manner his own very definite views as to the solution of the 'Riddle of the Universe,' are perhaps a sufficient justification of an attempt to lay before you the difficulties which surround some of these questions.

To keep the discussion within reasonable limits I shall illustrate the principles under review by means of the atomic theory, with comparatively little reference to the ether, and we may also at first confine our attention to inanimate objects.

The Construction of a Model of Nature.

A natural philosopher, to use the old phrase, even if only possessed of the most superficial knowledge, would attempt to bring some order into the results of his observation of Nature by grouping together statements with regard to phenomena which are obviously related. The aim of modern science goes far beyond this. It not only shows that many phenomena are related which at first sight have little or nothing in common, but, in so doing, also attempts to explain the relationship.

Without spending time on a discussion of the meaning of the word 'explanation,' it is sufficient to say that our efforts to establish relationships between phenomena often take the form of attempting to prove that, if a limited number of assumptions are granted as to the constitution of matter, or as to the existence of quasi-material entities, such as caloric, electricity, and the ether, a wide range of observed facts falls into order as a necessary consequence of the assumptions. The question at issue is whether the hypotheses which are at the base of the scientific theories now most generally accepted are to be regarded as accurate descriptions of the constitution of the universe around us, or merely as convenient fictions.

Convenient fictions be it observed, for even if they are fictions they are not useless. From the practical point of view it is a matter of secondary importance whether our theories and assumptions are correct, if only they guide us to results which are in accord with facts. The whole fabric of scientific theory may be regarded merely as a gigantic 'aid to memory'; as a means for producing apparent order out of disorder by codifying the observed facts and laws in accordance with an artificial system, and thus arranging our knowledge under a comparatively small number of heads. The simplification introduced by a scheme which, however imperfect it may be, enables us to argue from a few first principles, makes theories of practical use. By means of them we can foresee the results of combinations of causes which would otherwise elude us. We can predict future events, and can even attempt to argue back from the present to the unknown past.

But it is possible that these advantages might be attained by means of axioms, assumptions, and theories based on very false ideas. A person who thought that a river was really a streak of blue paint might learn as much about its direction from a map as one who knew it as it is. It is thus conceivable that we might be able, not indeed to construct, but to imagine, something more than a mere map or diagram, something which might even be called a working model of inanimate objects, which was nevertheless very unlike the realities of nature. Of course, the agreement between the action of the model and the behaviour of the things it was designed to represent would probably be imperfect, unless the one were a facsimile of the other; but it is conceivable that the correlation of natural phenomena could be imitated,

with a large measure of success, by means of an imaginary machine, which shared with a map or diagram the characteristic that it was in many ways unlike the things it represented, but might be compared to a model in that the behaviour of the things represented could be predicted from that of the corresponding parts of the machine.

We might even go a step further. If the laws of the working of the model could be expressed by abstractions, as, for example, by mathematical formulæ, then, when the formulæ were obtained, the model might be discarded, as probably unlike that which it was made to imitate, as a mere aid in the construction of equations, to be thrown aside when the perfect structure of mathematical symbols was erected.

If this course were adopted we should have given up the attempt to know more of the nature of the objects which surround us than can be gained by direct observation, but might nevertheless have learned how these objects would behave under given circumstances.

We should have abandoned the hope of a physical explanation of the properties of inanimate Nature, but should have secured a mathematical description of her operations.

There is no doubt that this is the easiest path to follow. Criticism is avoided if we admit from the first that we cannot go below the surface; cannot know anything about the constitution of material bodies; but must be content with formulating a description of their behaviour by means of laws of Nature expressed by equations.

But if this is to be the end of the study of Nature, it is evident that the construction of the model is not an essential part of the process. The model is used merely as an aid to thinking; and if the relation of phenomena can be investigated without it, so much the better. The highest form of theory—it may be said—the widest kind of generalisation, is that which has given up the attempt to form clear mental pictures of the constitution of matter, which expresses the facts and the laws by language and symbols which lead to results that are true, whatever be our view as to the real nature of the objects with which we deal. From this point of view the atomic theory becomes not so much false as unnecessary; it may be regarded as an attempt to give an unnatural precision to ideas which are and must be vague.

Thus, when Rumford found that the mere friction of metals produced heat in unlimited quantity, and argued that heat was therefore a mode of motion, he formed a clear mental picture of what he believed to be occurring. But his experiments may be quoted as proving only that energy can be supplied to a body in indefinite quantity, and that when supplied by doing work against friction it appears in the form of heat.

By using this phraseology we exchange a vivid conception of moving atoms for a colourless statement as to heat energy, the real nature of which we do not attempt to define; and methods which thus evade the problem of the nature of the things which the symbols in our equations represent have been prosecuted with striking success, at all events

within the range of a limited class of phenomena. A great school of chemists, building upon the thermodynamics of Willard Gibbs and the intuition of Van 't Hoff, have shown with wonderful skill that, if a sufficient number of the data of experiment are assumed, it is possible, by the aid of thermodynamics, to trace the form of the relations between many physical and chemical phenomena without the help of the atomic theory.

But this method deals only with matter as our coarse senses know it; it does not pretend to penetrate beneath the surface.

It is therefore with the greatest respect for its authors, and with a full recognition of the enormous power of the weapons employed, that I venture to assert that the exposition of such a system of tactics cannot be regarded as the last word of science in the struggle for the truth.

Whether we grapple with them, or whether we shirk them; however much or however little we can accomplish without answering them, the questions still force themselves upon us: Is matter what it seems to be? Is interplanetary space full or empty? Can we argue back from the direct impressions of our senses to things which we cannot directly perceive; from the phenomena displayed by matter to the constitution of matter itself?

It is these questions which we are discussing to-night, and we may therefore, as far as the present address is concerned, put aside, once for all, methods of scientific exposition in which an attempt to form a mental picture of the constitution of matter is practically abandoned, and devote ourselves to the inquiries whether the effort to form such a picture is legitimate, and whether we have any reason to believe that the sketch which science has already drawn is to some extent a copy, and not a mere diagram, of the truth.

Successive Steps in the Analysis of Matter.

In dealing, then, with the question of the constitution of matter and the possibility of representing it accurately, we may grant at once that the ultimate nature of things is, and must remain, unknown; but it does not follow that immediately below the complexities of the superficial phenomena which affect our senses there may not be a simpler machinery of the existence of which we can obtain evidence, indirect indeed but conclusive.

The fact that the apparent unity which we call the atmosphere can be resolved into a number of different gases is admitted; though the ultimate nature of oxygen, nitrogen, argon, carbonic acid, and water vapour is as unintelligible as that of air as a whole, so that the analysis of air, taken by itself, may be said to have substituted many incomprehensibles for one.

Nobody, however, looks at the question from this point of view. It is recognised that an investigation into the proximate constitution of things may be useful and successful, even if their ultimate nature is beyond our ken.

Nor need the analysis stop at the first step. Water vapour and carbonic acid, themselves constituents of the atmosphere, are in turn resolved into their elements hydrogen, oxygen, and carbon, which, without a formal discussion of the criteria of reality, we may safely say are as real as air itself.

Now, at what point must this analysis stop if we are to avoid crossing the boundary between fact and fiction? Is there any fundamental difference between resolving air into a mixture of gases and resolving an elementary gas into a mixture of atoms and ether?

There are those who cry halt! at the point at which we divide a gas into molecules, and their first objection seems to be that molecules and atoms cannot be directly perceived, cannot be seen or handled, and are mere conceptions, which have their uses, but cannot be regarded as realities.

It is easiest to reply to this objection by an illustration.

The rings of Saturn appear to be continuous masses separated by circular rifts. This is the phenomenon which is observed through a telescope. By no known means can we ever approach or handle the rings; yet everybody who understands the evidence now believes that they are not what they appear to be, but consist of minute moonlets, closely packed indeed, but separate the one from the other.

In the first place Maxwell proved mathematically that if a Saturnian ring were a continuous solid or fluid mass it would be unstable and would necessarily break into fragments. In the next place, if it were possible for the ring to revolve like a solid body, the inmost parts would move slowest, while a satellite moves faster the nearer it is to a planet. Now spectroscopic observation, based on the beautiful method of Sir W. Huggins, shows not only that the inner portions of the ring move the more rapidly, but that the actual velocities of the outer and inner edges are in close accord with the theoretical velocities of satellites at like distances from the planet.

This and a hundred similar cases prove that it is possible to obtain convincing evidence of the constitution of bodies between whose separate parts we cannot directly distinguish, and I take it that a physicist who believes in the reality of atoms thinks that he has as good reason for dividing an apparently continuous gas into molecules as he has for dividing the apparently continuous Saturnian rings into satellites. If he is wrong it is not the fact that molecules and satellites alike cannot be handled and cannot be seen as individuals, that constitutes the difference between the two cases.

It may, however, be urged that atoms and the ether are alleged to have properties different from those of matter in bulk, of which alone our senses take direct cognisance, and that therefore it is impossible to prove their existence by evidence of the same cogency as that which may prove the existence of a newly discovered variety of matter or of a portion of matter too small or too distant to be seen.

This point is so important that it requires full discussion, but in dealing with it, it is necessary to distinguish carefully between the validity of the arguments which support the earlier and more fundamental propositions of the theory, and the evidence brought forward to justify mere speculative applications of its doctrines which might be abandoned without discarding the theory itself. The proof of the theory must be carried out step by step.

The first step is concerned wholly with some of the most general properties of matter, and consists in the proof that those properties are either absolutely unintelligible, or that, in the case of matter of all kinds, we are subject to an illusion similar to that the results of which we admit in the case of Saturn's rings, clouds, smoke, and a number of similar instances. The believer in the atomic theory asserts that matter exists in a particular state, that it consists of parts which are separate and distinct the one from the other, and as such are capable of independent movements.

Up to this point no question arises as to whether the separate parts are, like grains of sand, mere fragments of matter; or whether, though they are the bricks of which matter is built, they have, as individuals, properties different from those of masses of matter large enough to be directly perceived: If they are mere fragments of ordinary matter, they cannot be used as aids in explaining those qualities of matter which they themselves share.

We cannot explain things by the things themselves. If it be true that the properties of matter are the product of an underlying machinery, that machinery cannot itself have the properties which it produces, and must, to that extent at all events, differ from matter in bulk as it is directly presented to the senses.

If, however, we can succeed in showing that if the separate parts have a limited number of properties (different, it may be, from those of matter in bulk), the many and complicated properties of matter can be explained, to a considerable extent, as consequences of the constitution of these separate parts; we shall have succeeded in establishing, with regard to quantitative properties, a simplification similar to that which the chemist has established with regard to varieties of matter. The many will have been reduced to the few.

The proofs of the physical reality of the entities discovered by means of the two analyses must necessarily be different. The chemist can actually produce the elementary constituents into which he has resolved a compound mass. No physicist or chemist can produce a single atom separated from all its fellows, and show that it possesses the elementary qualities he assigns to it. The cogency of the evidence for any suggested constitution of atoms must vary with the number of facts which the hypothesis that they possess that constitution explains.

Let us take, then, two steps in their proper order, and inquire, first,

whether there is valid ground for believing that all matter is made up of discrete parts; and secondly, whether we can have any knowledge of the constitution or properties which those parts possess.

The Coarse-grainedness of Matter.

Matter in bulk appears to be continuous. Such substances as water or air appear to the ordinary observer to be perfectly uniform in all their properties and qualities, in all their parts.

The hasty conclusion that these bodies are really uniform is, nevertheless, unthinkable.

In the first place the phenomena of diffusion afford conclusive proof that matter when apparently quiescent is in fact in a state of internal commotion. I need not recapitulate the familiar evidence to prove that gases and many liquids when placed in communication interpenetrate or diffuse into each other; or that air, in contact with a surface of water, gradually becomes laden with water vapour, while the atmospheric gases in turn mingle with the water. Such phenomena are not exhibited by liquids and gases alone, nor by solids at high temperatures only. Sir W. Roberts Austen has placed pieces of gold and lead in contact at a temperature of 18° C. After four years the gold had travelled into the lead to such an extent that not only were the two metals united, but, on analysis, appreciable quantities of the gold were detected even at a distance of more than 5 millimetres from the common surface, while within a distance of three-quarters of a millimetre from the surface gold had penetrated into the lead to the extent of 1 oz. 6 dwts. per ton, an amount which could have been profitably extracted.

Whether it is or is not possible to devise any other intelligible account of the cause of such phenomena, it is certain that a simple and adequate explanation is found in the hypothesis that matter consists of discrete parts in a state of motion, which can penetrate into the spaces between the corresponding parts of surrounding bodies.

The hypothesis thus framed is also the only one which affords a rational explanation of other simple and well known facts. If matter is regarded as a continuous medium the phenomena of expansion are unintelligible. There is, apparently, no limit to the expansion of matter, or, to fix our attention on one kind of matter, let us say to the expansion of a gas; but it is inconceivable that a continuous material which fills or is present in every part of a given space could also be present in every part of a space a million times as great. Such a statement might be made of a mathematical abstraction; it cannot be true of any real substance or thing. If, however, matter consists of discrete particles, separated from each other either by empty space or by something different from themselves, we can at once understand that expansion and contraction may be nothing more than the mutual separation or approach of these particles.

Again, no clear mental picture can be formed of the phenomena of

heat unless we suppose that heat is a mode of motion. In the words of Rumford, it is 'extremely difficult, if not quite impossible, to form any distinct idea of anything capable of being excited and communicated in the manner the heat was excited and communicated in [his] experiment [on friction] except it be motion.'[1] And if heat be motion there can be no doubt that it is the fundamental particles of matter which are moving. For the motion is not visible, is not motion of the body as a whole, while diffusion, which is a movement of matter, goes on more quickly as the temperature rises, thereby proving that the internal motions have become more rapid, which is exactly the result which would follow if these were the movements which constitute sensible heat.

Combining, then, the phenomena of diffusion, expansion, and heat, it is not too much to say that no hypotheses which make them intelligible have ever been framed other than those which are at the basis of the atomic theory.

Other considerations also point to the same conclusion. Many years ago Lord Kelvin gave independent arguments, based on the properties of gases, on the constitution of the surfaces of liquids, and on the electric properties of metals, all of which indicate that matter is, to use his own phrase, coarse-grained—that it is not identical in constitution throughout, but that adjacent minute parts are distinguishable from each other by being either of different natures or in different states.

And here it is necessary to insist that all these fundamental proofs are independent of the nature of the particles or granules into which matter must be divided.

The particles, for instance, need not be different in kind from the medium which surrounds and separates them. It would suffice if they were what may be called singular parts of the medium itself, differing from the rest only in some peculiar state of internal motion or of distortion, or by being in some other way earmarked as distinct individuals. The view that the constitution of matter is atomic may and does receive support from theories in which definite assumptions are made as to the constitution of the atoms; but when, as is often the case, these assumptions introduce new and more recondite difficulties, it must be remembered that the fundamental hypothesis—that matter consists of discrete parts, capable of independent motions—is forced upon us by facts and arguments which are altogether independent of what the nature and properties of these separate parts may be.

As a matter of history the two theories, which are not by any means mutually exclusive, that atoms are particles which can be treated as distinct in kind from the medium which surrounds them, and that they are parts of that medium existing in a special state, have both played a large part in the theoretical development of the atomic hypothesis. The atoms of Waterston, Clausius, and Maxwell were particles. The vortex-atoms

[1] *Phil. Trans.*, 1798, p. 99.

of Lord Kelvin, and the strain-atoms (if I may call them so) suggested by Mr. Larmor, are states of a primary medium which constitutes a physical connection between them, and through which their mutual actions arise and are transmitted.

Properties of the Basis of Matter.

It is easy to show that, whichever alternative be adopted, we are dealing with something, whether we consider it under the guise of separate particles or of differentiated portions of the medium, which has properties different from those of matter in bulk.

For if the basis of matter had the same constitution as matter, the irregular heat movements could hardly be maintained either against the viscosity of the medium or the frittering away of energy of motion which would occur during the collisions between the particles. Thus, even in the case in which a hot body is prevented from losing heat to surrounding objects, its sensible heat should spontaneously decay by a process of self-cooling. No such phenomenon is known, and though on this, as on all other points, the limits of our knowledge are fixed by the uncertainty of experiment, we are compelled to admit that, to all appearance, the fundamental medium, if it exists, is unlike a material medium, in that it is non-viscous; and that the particles, if they exist, are so constituted that energy is not frittered away when they collide. In either case, we are dealing with something different from matter itself in the sense that, though it is the basis of matter, it is not identical in all its properties with matter.

The idea, therefore, that entities exist possessing properties different from those of matter in bulk is not introduced at the end of a long and recondite investigation to explain facts with which none but experts are acquainted. It is forced upon us at the very threshold of our study of Nature. Either the properties of matter in bulk cannot be referred to any simpler structure, or that simpler structure must have properties different from those of matter in bulk as we directly knew it—properties which can only be inferred from the results which they produce.

No *a priori* argument against the possibility of our discovering the existence of quasi-material substances, which are nevertheless different from matter, can prove the negative proposition that such substances cannot exist. It is not a self-evident truth that no substance other than ordinary matter can have an existence as real as that of matter itself. It is not axiomatic that matter cannot be composed of parts whose properties are different from those of the whole. To assert that even if such substances and such parts exist no evidence however cogent could convince us of their existence is to beg the whole question at issue; to decide the cause before it has been heard.

We must therefore adhere to the standpoint adopted by most scientific men, viz., that the question of the existence of ultra-physical entities, such as atoms and the ether, is to be settled by the evidence, and must not be ruled out as inadmissible on *a priori* grounds.

On the other hand, it is impossible to deny that, if the mere entry on the search for the concealed causes of physical phenomena is not a trespass on ground we have no right to explore, it is at all events the beginning of a dangerous journey.

The wraiths of phlogiston, caloric, luminiferous corpuscles, and a crowd of other phantoms haunt the investigator, and as the grim host vanishes into nothingness he cannot but wonder if his own conceptions of atoms and of the ether

> 'shall dissolve,
> And, like this insubstantial pageant faded,
> Leave not a wrack behind.'

But though science, like Bunyan's hero, has sometimes had to pass through the 'Valley of Humiliation,' the spectres which meet it there are not formidable if they are boldly faced. The facts that mistakes have been made, that theories have been propounded, and for a time accepted, which later investigations have disproved, do not necessarily discredit the method adopted. In scientific theories, as in the world around us, there is a survival of the fittest, and Dr. James Ward's unsympathetic account of the blunders of those whose work has shed glory on the nineteenth century, might *mutatis mutandis* stand for a description of the history of the advance of civilisation. 'The story of the progress so far,' he tells us, 'is briefly this: Divergence between theory and fact one part of the way, the wreckage of abandoned fictions for the rest, with an unattainable goal of phenomenal nihilism and ultra-physical mechanism beyond.'[1]

'The path of progress,' says Professor Karl Pearson, 'is strewn with the wreck of nations. Traces are everywhere to be seen of the hecatombs of inferior races, and of victims who found not the narrow way to the greater perfection. Yet these dead peoples are, in very truth, the stepping-stones on which mankind has arisen to the higher intellectual and deeper emotional life of to-day.'[2]

It is only necessary to add that the progress of society is directed towards an unattainable goal of universal contentment, to make the parallel complete.

And so, in the one case as in the other, we may leave 'the dead to bury their dead.' The question before us is not whether we too may not be trusting to false ideas, erroneous experiments, evanescent theories. No doubt we are; but, without making an insolent claim to be better than our fathers, we may fairly contend that, amid much that is uncertain and temporary, some of the fundamental conceptions, some of the root-ideas of science, are so grounded on reason and fact that we cannot but regard them as an aspect of the very truth.

Enough has, perhaps, now been said on this point for my immediate

[1] James Ward, *Naturalism and Agnosticism*, vol. i. p. 153.
[2] Karl Pearson *National Life from the Standpoint of Science*, p. 62.

purpose. The argument as to the constitution of matter could be developed further in the manner I have hitherto adopted, viz., by a series of propositions, the proof of each of which is based upon a few crucial phenomena. In particular, if matter is divided into moving granules or particles, the phenomenon of cohesion proves that there must be mutual actions between them analogous to those which take place between large masses of matter, and which we ascribe to force, thereby indicating the regular, unvarying operation of active machinery which we have not yet the means of adequately understanding. For the moment, I do not wish to extend the line of reasoning that has been followed. My main object is to show that the notion of the existence of ultra-physical entities and the leading outlines of the atomic theory are forced upon us at the beginning of our study of Nature, not only by *a priori* considerations, but in the attempt to comprehend the results of even the simplest observation. These outlines cannot be effaced by the difficulties which undoubtedly arise in filling up the picture. The cogency of the proof that matter is coarse-grained is in no way affected by the fact that we may have grave doubts as to the nature of the granules. Nay, it is of the first importance to recognise that, though the fundamental assumptions of the atomic theory receive overwhelming support from a number of more detailed arguments, they are themselves almost of the nature of axioms, in that the simplest phenomena are unintelligible if they are abandoned.

The Range of the Atomic Theory.

It would be most unfair, however, to the atomic theory to represent it as depending on one line of reasoning only, or to treat its evidence as bounded by the very general propositions I have discussed.

It is true that as the range of the theory is extended the fundamental conception that matter is granular must be expanded and filled in by supplementary hypotheses as to the constitution of the granules. It may also be admitted that no complete or wholly satisfactory description of that constitution can as yet be given ; that perfection has not yet been attained here or in any other branch of science ; but the number of facts which can be accounted for by the theory is very large compared with the number of additional hypotheses which are introduced ; and the cumulative weight of the additional evidence obtained by the study of details is such as to add greatly to the strength of the conviction that, in its leading outlines, the theory is true.

It was originally suggested by the facts of chemistry, and though, as we have seen, a school of chemists now thrusts it into the background, it is none the less true, in the words of Dr. Thorpe, that 'every great advance in chemical knowledge during the last ninety years finds its interpretation in [Dalton's] theory.'[1]

The principal mechanical and thermal properties of gases have been

[1] Thorpe, *Essays on Historical Chemistry*, 1894, p. 368.

explained, and in large part discovered, by the aid of the atomic theory; and, though there are outstanding difficulties, they are, for the most part, related to the nature of the atoms and molecules, and do not affect the question as to whether they exist.

The fact that different kinds of light all travel at the same speed in interplanetary space, while they move at different rates in matter, is explained if matter is coarse-grained. But to attempt to sum up all this evidence would be to recite a text-book on physics. It must suffice to say that it is enormous in extent and varied in character, and that the atomic theory imparts a unity to all the physical sciences which has been attained in no other way.

I must, however, give a couple of instances of the wonderful success which has been achieved in the explanation of physical phenomena by the theory we are considering, and I select them because they are in harmony with the line of argument I have been pursuing.

When a piece of iron is magnetised its behaviour is different according as the magnetic force applied to it is weak, moderate, or strong. When a certain limit is passed the iron behaves as a non-magnetic substance to all further additions of magnetic force. With strong forces it does and with very weak forces it does not remain magnetised when the force ceases to act. Professor Ewing has imitated all the minute details of these complicated properties by an arrangement of small isolated compass needles to represent the molecules. It may fairly be said that as far as this particular set of phenomena is concerned a most instructive working model based on the molecular theory has not only been imagined but constructed.

The next illustration is no less striking. We may liken a crowd of molecules to a fog; but while the fog is admitted by everybody to be made up of separate globules of water, the critics of scientific method are sometimes apt to regard the molecules as mere fictions of the imagination. If, however, we could throw the molecules of a highly rarefied gas into such a state that vapour condensed on them, so that each became the centre of a water-drop, till the host of invisible molecules was, as it were, magnified by accretion into a visible mist, surely no stronger proof of their reality could be desired. Yet there is every reason to believe that something very like this has been accomplished by Mr. C. T. R. Wilson and Professor J. J. Thomson.

It is known that it is comparatively difficult to produce a fog in damp f the mixture consists of air and water-vapour alone. The presence ırticles of very fine dust facilitates the process. It is evident that the ur condenses on the dust particles and that a nucleus of some kind is ssary on which each drop may form. But electrified particles also as nuclei; for if a highly charged body from which electricity is ping be placed near a steam jet, the steam condenses; and a cloud is formed in dust-free air more easily than would otherwise be the case ectricity is discharged into it.

Again, according to accepted theory, when a current of electricity flows through a gas some of the atoms are divided into parts which carry positive and negative charges as they move in opposite directions, and unless this breaking-up occurs a gas does not conduct electricity. But a gas can be made a conductor merely by allowing the Röntgen rays or the radiation given off by uranium to fall upon it. A careful study of the facts shows that it is probable that some of the atoms have been broken up by the radiation, and that their oppositely electrified parts are scattered among their unaltered fellows. Such a gas is said to be ionised.

Thus by these two distinct lines of argument we come to the conclusions :—1st, that the presence of electrified particles promotes the formation of mist, and 2nd, that in an ionised gas such electrified particles are provided by the breaking-up of atoms.

The two conclusions will mutually support each other if it can be shown that a mist is easily formed in ionised air. This was tested by Mr. Wilson, who showed that in such air mist is formed as though nuclei were present, and thus in the cloud we have visible evidence of the presence of the divided atoms. If then we cannot handle the individual molecules we have at least some reason to believe that a method is known of seizing individuals, or parts of individuals, which are in a special state, and of wrapping other matter round them till each one is the centre of a discrete particle of a visible fog.

I have purposely chosen this illustration, because the explanation is based on a theory—that of ionisation—which is at present subjected to hostile criticism. It assumes that an electrical current is nothing more than the movement of charges of electricity. But magnets placed near to an electric current tend to set themselves at right angles to its direction ; a fact on which the construction of telegraphic instruments is based. Hence if the theory be true, a similar effect ought to be produced by a moving charge of electricity. This experiment was tried many years ago in the laboratory of Helmholtz by Rowland, who caused a charged disc to spin rapidly near a magnet. The result was in accord with the theory ; the magnet moved as though acted upon by an electric current. Of late, however, M. Crémieu has investigated the matter afresh, and has obtained results which, according to his interpretation, were inconsistent with that of Rowland.

M. Crémieu's results are already the subject of controversy,[1] and are, I believe, likely to be discussed in the Section of Physics. This is not the occasion to enter upon a critical discussion of the question at issue, and I refer to it only to point out that though, if M. Crémieu's result were upheld, our views as to electricity would have to be modified, the foundations of the atomic theory would not be shaken.

[1] See *Phil. Mag.*, July 1901, p. 144; and *Johns Hopkins University Circulars*, xx. No. 152, May–June 1901, p. 78.

It is, however, from the theory of ions that the most far-reaching speculations of science have recently received unexpected support. The dream that matter of all kinds will some day be proved to be fundamentally the same has survived many shocks. The opinion is consistent with the great generalisation that the properties of elements are a periodic function of their atomic weights. Sir Norman Lockyer has long been a prominent exponent of the view that the spectra of the stars indicate the reduction of our so-called elements to simpler forms, and now Professor J. J. Thomson believes that we can break off from an atom a part, the mass of which is not more than one thousandth of the whole, and that these corpuscles, as he has named them, are the carriers of the negative charge in an electric current. If atoms are thus complex, not only is the *a priori* probability increased that the different structures which we call elements may all be built of similar bricks, but the discovery by Lenard that the ease with which the corpuscles penetrate different bodies depends only on the density of the obstacles, and not on their chemical constitution, is held by Professor Thomson to be 'a strong confirmation of the view that the atoms of the elementary substances are made up of simpler parts, all of which are alike.'[1] On the present occasion, however, we are occupied rather with the foundations than with these ultimate ramifications of the atomic theory; and having shown how wide its range is, I must, to a certain extent, retrace my steps and return to the main line of my argument.

The Properties of Atoms and Molecules.

For if it be granted that the evidence that matter is coarse-grained and is formed of separate atoms and molecules is too strong to be resisted, it may still be contended that we can know little or nothing of the sizes and properties of the molecules.

It must be admitted that though the fundamental postulates are always the same, different aspects of the theory, which have not in all cases been successfully combined, have to be developed when it is applied to different problems; but in spite of this there is little doubt that we have some fairly accurate knowledge of molecular motions and magnitudes.

If a liquid is stretched into a very thin film, such as a soap bubble, we should expect indications of a change in its properties when the thickness of the film is not a very large multiple of the average distance between two neighbouring molecules. In 1890 Sohncke[2] detected evidence of such a change in films of the average thickness of 106 millionths

[1] For the most recent account of this subject see an article on 'Bodies smaller than Atoms,' by Professor J. J. Thomson in the *Popular Science Monthly* (The Science Press), August 1901.

[2] *Wied. Ann.*, 1890, xl. pp. 345–355.

of a millimetre ($\mu\mu$), and quite recently Rudolph Weber found it in an oil-film when the thickness was 115 $\mu\mu$.[1]

Taking the mean of these numbers and combining the results of different variants of the theory we may conclude that a film should become unstable and tend to rupture spontaneously somewhere between the thicknesses of 110 and 55 $\mu\mu$, and Professor Reinold and I found by experiment that this instability is actually exhibited between the thicknesses of 96 and 45 $\mu\mu$.[2] There can therefore be little doubt that the first approach to molecular magnitudes is signalled when the thickness of a film is somewhat less than 100 $\mu\mu$, or 4 millionths of an inch.

Thirteen years ago I had the honour of laying before the Chemical Society a résumé of what was then known on these subjects,[3] and I must refer to that lecture or to the most recent edition of O. E. Meyer's work on the kinetic theory of gases[4] for the evidence that various independent lines of argument enable us to estimate quantities very much less than 4 millionths of an inch, which is perhaps from 500 to 1,000 times greater than the magnitude which, in the present state of our knowledge, we can best describe as the diameter of a molecule.

Confining our attention, however, to the larger quantities, I will give one example to show how strong is the cumulative force of the evidence as to our knowledge of the magnitudes of molecular quantities.

We have every reason to believe that though the molecules in a gas frequently collide with each other, yet in the case of the more perfect gases the time occupied in collisions is small compared with that in which each molecule travels undisturbed by its fellows. The average distance travelled between two successive encounters is called the mean free path, and, for the reason just given, the question of the magnitude of this distance can be attacked without any precise knowledge of what a molecule is, or of what happens during an encounter.

Thus the mean free path can be determined, by the aid of the theory, either from the viscosity of the gas or from the thermal conductivity. Using figures given in the latest work on the subject,[5] and dealing with one gas only, as a fair sample of the rest, the lengths of the mean free path of hydrogen as determined by these two independent methods differ only by about 3 per cent. Further, the mean of the values which I gave in the lecture already referred to differed only by about 6 per cent. from the best modern result, so that no great change has been introduced during the last thirteen years.

It may, however, be argued that these concordant values are all obtained by means of the same theory, and that a common error may affect them all. In particular, some critics have of late been inclined to

[1] *Annalen der Physik*, 1901, iv. pp. 706–721.

[2] *Phil. Trans.*, 1893, 184, pp. 505–529.

[3] *Chem. Soc. Trans.*, liii., March 1888, pp. 222–262.

[4] *Kinetic Theory of Gases*, O. E. Meyer, 1899. Translated by R. E. Baynes.

[5] Meyer's *Kinetic Theory of Gases* (see above).

discredit the atomic theory by pointing out that the strong statements which have sometimes been made as to the equality, among themselves, of atoms or molecules of the same kind may not be justified, as the equality may be that of averages only, and be consistent with a considerable variation in the sizes of individuals.

Allowing this argument more weight than it perhaps deserves, it is easy to show that it cannot affect seriously our knowledge of the length of the mean free path.

Professor George Darwin[1] has handled the problem of a mixture of unequal spherical bodies in the particular case in which the sizes are distributed according to the law of errors, which would involve far greater inequalities than can occur among atoms. Without discussing the precise details of his problem it is sufficient to say that in the case considered by him the length of the mean free path is $\frac{7}{11}$ of what it would be if the particles were equal. Hence were the inequalities of atoms as great as in this extreme case, the reduction of the mean free path in hydrogen could only be from 185 to 119 $\mu\mu$; but they must be far less, and therefore the error, if any, due to this cause could not approach this amount. It is probably inappreciable.

Such examples might be multiplied, but the one I have selected is perhaps sufficient to illustrate my point, viz., that considerable and fairly accurate knowledge can be obtained as to molecular quantities by the aid of theories the details of which are provisional, and are admittedly capable of improvement.

Is the Model Unique?

But the argument that a correct result may sometimes be obtained by reasoning on imperfect hypotheses raises the question as to whether another danger may not be imminent. To be satisfactory our model of Nature must be unique, and it must be impossible to imagine any other which agrees equally well with the facts of experiment. If a large number of hypotheses could be framed with equal claims to validity, that fact would alone raise grave doubts as to whether it were possible to distinguish between the true and the false. Thus Professor Poincaré has shown that an infinite number of dynamical explanations can be found for any phenomenon which satisfies certain conditions. But though this consideration warns us against the too ready acceptance of explanations of isolated phenomena, it has no weight against a theory which embraces so vast a number of facts as those included by the atomic theory. It does not follow that, because a number of solutions are all formally dynamical, they are therefore all equally admissible. The pressure of a gas may be explained as the result of a shower of blows delivered by molecules, or by a repulsion between the various parts of a continuous medium. Both solutions are expressed in dynamical language; but one is, and the other

[1] *Phil. Trans.*, 180.

is not, compatible with the observed phenomena of expansion. The atomic theory must hold the field until another can be found which is not inferior as an explanation of the fundamental difficulties as to the constitution of matter, and is, at the same time, not less comprehensive.

On the whole, then, the question as to whether we are attempting to solve a problem which has an infinite number of solutions may be put aside until one solution has been found which is satisfactory in all its details. We are in a sufficient difficulty about that to make the rivalry of a second of the same type very improbable.

The Phenomena of Life.

But it may be asked—nay, it has been asked—may not the type of our theories be radically changed? If this question does not merely imply a certain distrust in our own powers of reasoning, it should be supported by some indication of the kind of change which is conceivable.

Perhaps the chief objection which can be brought against physical theories is that they deal only with the inanimate side of Nature, and largely ignore the phenomena of life. It is therefore in this direction, if in any, that a change of type may be expected. I do not propose to enter at length upon so difficult a question, but, however we may explain or explain away the characteristics of life, the argument for the truth of the atomic theory would only be affected if it could be shown that living matter does not possess the thermal and mechanical properties, to account for which the atomic theory has been framed. This is so notoriously not the case that there is the gravest doubt whether life can in any way interfere with the action within the organism of the laws of matter in bulk belonging to the domain of mechanics, physics, and chemistry.

Probably the most cautious opinion that could now be expressed on this question is that, in spite of some outstanding difficulties which have recently given rise to what is called Neovitalism, there is no conclusive evidence that living matter can suspend or modify any of the natural laws which would affect it if it were to cease to live. It is possible that though subject to these laws the organism while living may be able to employ, or even to direct, their action within itself for its own benefit, just as it unquestionably does make use of the processes of external nature for its own purposes; but if this be so, the seat of the controlling influence is so withdrawn from view that on the one hand its very existence may be denied, while, on the other hand, Professor Hæckel, following Vogt, has recently asserted that 'matter and ether are not dead, and only moved by extrinsic force; but they are endowed with sensation and will; they experience an inclination for condensation, a dislike for strain; they strive after the one and struggle against the other.'[1]

But neither unproved assertions of this kind nor the more refined attempts that have been made by others to bring the phenomena of life

[1] *Riddle of the Universe* (English translation), 1900, p. 380.

and of dead matter under a common formula touch the evidence for the atomic theory. The question as to whether matter consists of elements capable of independent motion is prior to and independent of the further questions as to what these elements are, and whether they are alive or dead.

The physicist, if he keeps to his business, asserts, as the bases of the atomic theory, nothing more than that he who declines to admit that matter consists of separate moving parts must regard many of the simplest phenomena as irreconcilable and unintelligible, in spite of the fact that means of reconciling them are known to everybody, in spite of the fact that the reconciling theory gives a general correlation of an enormous number of phenomena in every branch of science, and that the outstanding difficulties are connected, not so much with the fundamental hypotheses that matter is composed of distinguishable entities which are capable of separate motions as with the much more difficult problem of what these entities are.

On these grounds the physicist may believe that, though he cannot handle or see them, the atoms and molecules are as real as the ice crystals in a cirrus cloud which he cannot reach; as real as the unseen members of a meteoric swarm whose death-glow is lost in the sunshine, or which sweep past us, unentangled, in the night.

If the confidence that his methods are weapons with which he can fight his way to the truth were taken from the scientific explorer, the paralysis which overcomes those who believe that they are engaged in a hopeless task would fall upon him.

Physiology has specially flourished since physiologists have believed that it is possible to master the physics and chemistry of the framework of living things, and since they have abandoned the attitude of those who placed in the foreground the doctrine of the vital force. To supporters of that doctrine the principle of life was not a hidden directing power which could perhaps whisper an order that the flood-gates of reservoirs of energy should now be opened and now closed, and could, at the most, work only under immutable conditions to which the living and the dead must alike submit. On the contrary, their vital force pervaded the organism in all its parts. It was an active and energetic opponent of the laws of physics and chemistry. It maintained its own existence not by obeying but by defying them; and though destined to be finally overcome in the separate campaigns of which each individual living creature is the scene, yet like some guerilla chieftain it was defeated here only to reappear there with unabated confidence and apparently undiminished force.

This attitude of mind checked the advance of knowledge. Difficulty could be evaded by a verbal formula of explanation which in fact explained nothing. If the mechanical, or physical, or chemical causes of a phenomenon did not lie obviously upon the surface, the investigator was tempted to forego the toil of searching for them below; it was easier to say that the vital force was the cause of the discrepancy, and that it was

hopeless to attempt to account for the action of a principle which was incomprehensible in its nature.

For the physicist the danger is no less serious though it lies in a somewhat different direction. At present he is checked in his theories by the necessity of making them agree with a comparatively small number of fundamental hypotheses. If this check were removed his fancy might run riot in the wildest speculations, which would be held to be legitimate if only they led to formulæ in harmony with facts. But the very habit of regarding the end as everything, and the means by which it was attained as unimportant, would prevent the discovery of those fragments of truth which can only be uncovered by the painful process of trying to make inconsistent theories agree, and using all facts, however remote, as the tests of our central generalisation.

'Science,' said Helmholtz, 'Science, whose very object it is to comprehend Nature, must start with the assumption that Nature is comprehensible.' And again: 'The first principle of the investigator of Nature is to assume that Nature is intelligible to us, since otherwise it would be foolish to attempt the investigation at all.' These axioms do not assume that all the secrets of the universe will ultimately be laid bare, but that a search for them is hopeless if we undertake the quest with the conviction that it will be in vain. As applied to life they do not deny that in living matter something may be hidden which neither physics nor chemistry can explain, but they assert that the action of physical and chemical forces in living bodies can never be understood, if at every difficulty and at every check in our investigations we desist from further attempts in the belief that the laws of physics and chemistry have been interfered with by an incomprehensible vital force. As applied to physics and chemistry they do not mean that all the phenomena of life and death will ultimately be included in some simple and self-sufficing mechanical theory; they do mean that we are not to sit down contented with paradoxes such as that the same thing can fill both a large space and a little one; that matter can act where it is not, and the like, if by some reasonable hypothesis, capable of being tested by experiment, we can avoid the acceptance of these absurdities. Something will have been gained if the more obvious difficulties are removed, even if we have to admit that in the background there is much that we cannot grasp.

The Limits of Physical Theories.

And this brings me to my last point. It is a mistake to treat physical theories in general, and the atomic theory in particular, as though they were parts of a scheme which has failed if it leaves anything unexplained, which must be carried on indefinitely on exactly the same principles, whether the ultimate results are, or are not, repugnant to common sense.

Physical theories begin at the surface with phenomena which directly

affect our senses. When they are used in the attempt to penetrate deeper into the secrets of Nature it is more than probable that they will meet with insuperable barriers, but this fact does not demonstrate that the fundamental assumptions are false, and the question as to whether any particular obstacle will be for ever insuperable can rarely be answered with certainty.

Those who belittle the ideas which have of late governed the advance of scientific theory too often assume that there is no alternative between the opposing assertions that atoms and the ether are mere figments of the scientific imagination, or that, on the other hand, a mechanical theory of the atoms and of the ether, which is now confessedly imperfect, would, if it could be perfected, give us a full and adequate representation of the underlying realities.

For my own part I believe that there is a *via media*.

A man peering into a darkened room, and describing what he thinks he sees, may be right as to the general outline of the objects he discerns, wrong as to their nature and their precise forms. In his description fact and fancy may be blended, and it may be difficult to say where the one ends and the other begins; but even the fancies will not be worthless if they are based on a fragment of truth, which will prevent the explorer from walking into a looking-glass or stumbling over the furniture. He who saw 'men as trees walking' had at least a perception of the fundamental fact that something was in motion around him.

And so, at the beginning of the twentieth century, we are neither forced to abandon the claim to have penetrated below the surface of Nature, nor have we, with all our searching, torn the veil of mystery from the world around us.

The range of our speculations is limited both in space and time: in space, for we have no right to claim, as is sometimes done, a knowledge of the 'infinite universe'; in time, for the cumulative effects of actions which might pass undetected in the short span of years of which we have knowledge, may, if continued long enough, modify our most profound generalisations. If some such theory as the vortex-atom theory were true, the faintest trace of viscosity in the primordial medium would ultimately destroy matter of every kind. It is thus a duty to state what we believe we know in the most cautious terms, but it is equally a duty not to yield to mere vague doubts as to whether we can know anything.

If no other conception of matter is possible than that it consists of distinct physical units—and no other conception has been formulated which does not blur what are otherwise clear and definite outlines—if it is certain, as it is, that vibrations which cannot be propagated by ordinary matter travel through space, the two foundations of physical theory are well and truly laid. It may be granted that we have not yet framed a consistent image either of the nature of the atoms or of the ether in which they exist; but I have tried to show that in spite of the

tentative nature of some of our theories, in spite of many outstanding difficulties, the atomic theory unifies so many facts, simplifies so much that is complicated, that we have a right to insist—at all events till an equally intelligible rival hypothesis is produced—that the main structure of our theory is true; that atoms are not merely helps to puzzled mathematicians, but physical realities.

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The Determination of the Components of Magnetic Force on Board Ship.—Report of the Committee, consisting of Professor A. W. RÜCKER (*Chairman*), Dr. C. H. LEES (*Secretary*), Lord KELVIN, Professor A. SCHUSTER, Captain E. W. CREAK, Professor W. STROUD, Mr. C. VERNON BOYS, and Mr. W. WATSON.

THE two instruments constructed a year ago, according to Captain Creak's design, and described below were tested at Kew and found satisfactory. They are now on board the 'Discovery.' A third instrument was ordered for use on board the German Antarctic ship 'Gauss,' and a fourth has since been constructed and was exhibited at the Glasgow Meeting of the Association.

On a New Form of Instrument for observing the Magnetic Dip and Intensity on Board Ship at Sea. By Captain E. W. CREAK, *C.B., R.N., F.R.S.*

One of the principal objects of the Antarctic expedition which sailed last month in the 'Discovery' is to make as complete a magnetic survey of the regions south of the fortieth parallel of south latitude as possible.

As the greater portion of that region is open sea, it is obvious that, with few chances of landing, the major portion of the survey must be conducted on board ship.

Previous experience in H.M.S. ships 'Erebus' and 'Terror' in 1839–43 (both wooden sailing ships) showed the serious effects of the iron in those ships in disturbing the magnetic instruments established on board. In the case of the 'Discovery,' with engines, boilers, and numerous other iron bodies on board, magnetic observations would have been almost impossible but for the precautions of first choosing a place for the magnetic observatory in the ship and then ensuring that no iron of any kind should be allowed to be placed within a 30-foot radius from that position.

The ship having thus been prepared, the important question of a reliable instrument for observing the magnetic dip and total force on

board of her arose. The only instrument hitherto used for this purpose has been Mr. R. W. Fox's dip and intensity apparatus invented in 1835, and little or no advance made in its construction since then. It certainly did valuable work in the Antarctic Magnetic Survey carried out in the 'Erebus' and 'Terror' under Sir James Ross, and also in the 'Challenger' expedition of 1872–76. An examination of the work done in the 'Challenger' under most favourable circumstances disclosed certain defects of a character which are quite inconsistent with the precision now required.

For example the needles could not be reversed, and hence there was constant necessity for frequent comparisons with an absolute instrument on land to obtain index errors. The magnetic moments of the needles were liable to change with no accurate means of knowing when the change took place, thus vitiating the sea observations of total force made by the method of a constant deflecting weight. Again the deflecting magnets used for a second method of obtaining the total force were liable to changes with no means for ascertaining the period of such change at sea. The Fox instrument was therefore not suited for the purposes in view.

Previous experience having shown me the excellent values of the absolute horizontal force to be obtained with the Barrow's Dip Circle fitted with Lloyd's needles, especially in high latitudes, I arranged for a series of experiments to ascertain the best methods of applying the principles of Lloyd's method to an instrument which could be used on a gimbal table on board ship. The use of needles with cylindrical axles resting on agate planes, either for dip or force, was impossible, and trials with various forms of needles and jewels resulted in my adopting the forms for both in the instrument exhibited. All the needles have axles terminating in a cone with the sharp point rounded off and highly polished. The jewels are highly polished sapphires fixed to the cross bars of the circle in which conical cavities, slightly larger than the axles of the needles, have been drilled and polished. The upper half of the jewel is removed, thus leaving a cup into which the axles of the needle can be lowered by the lifter provided. By this arrangement the needles can be retained in place even when the gimbal table, upon which the instrument is placed, is subject to irregular motions, due to those of the ship.

With the circle thus fitted the absolute dip and total force can be observed agreeably with the usual methods described in the Admiralty Manual of Scientific Enquiry.

As there might be a slight oscillation of the needle at times when the ship is unsteady in a seaway, I have arranged that the ends of the needles shall come so near the graduated arc that the readings may be made directly by the microscopes without the use of verniers, as in the land instruments.

To obviate friction between the axles of the needles and the jewels I have fitted a knob on the top of the circle, which should be gently rubbed with a circular motion of the ivory rubber provided.

The readings of the circle may be accurately made at night by placing a candle at the back of the circle when the light will be reflected by the ivory faces of the microscopes to the graduated arc.

The zero of the graduations on the base plate is so placed that whenever the magnetic direction of the ship's head is known by a compass

adjacent the plane of the circle can be immediately placed in the magnetic meridian without the trouble of finding the meridian by the usual method with the circle.

Two instruments of the kind described are now in use in the Antarctic ship 'Discovery,' and the German expedition in the Antarctic ship 'Gauss' have also one with two sets of needles.

Experiments for improving the Construction of Practical Standards for Electrical Measurements.—Report of the Committee, consisting of Lord RAYLEIGH (*Chairman*), Mr. R. T. GLAZEBROOK (*Secretary*), Lord KELVIN, Professors W. E. AYRTON, G. CAREY FOSTER, J. PERRY, W. G. ADAMS, *and* OLIVER J. LODGE, Dr. J. A. MUIRHEAD, Sir W. H. PREECE, Professors J. D. EVERETT, A. SCHUSTER, J. A. FLEMING, *and* J. J. THOMSON, Mr. W N. SHAW, Dr. J. T. BOTTOMLEY, Rev. T. C. FITZPATRICK, Dr. G. JOHNSTONE STONEY, Professor S. P. THOMPSON, Mr. J. RENNIE, Mr. E. H. GRIFFITHS, Professors A. W. RÜCKER, H. L. CALLENDAR, *and* Sir WM. C. ROBERTS AUSTEN, *and* Mr. GEORGE MATTHEY.

DURING the year a number of comparisons have been made at the Kew Observatory among the standard coils of the Association. The temperature conditions, however, in the temporary laboratory are not sufficiently satisfactory to make it desirable to report fully on the results ; it is perhaps sufficient to say that no evidence of any very marked change in the relative values has shown itself. It is hoped that the coils and other apparatus will be moved to Bushey during the autumn.

In the room which has been planned for their reception arrangements will be at hand for controlling the temperature, and the work of inter-comparison and control of the standards can go on as in former years at Cambridge.

Meanwhile some progress has been made in the preparations for the construction of mercury standards. A number of tubes of 'verre dur' have been examined, and some of these have been calibrated ; when the apparatus is set up at Bushey his work will go forward rapidly. There has also been during the year some demand for the issue of standards of capacity : this it has not been possible to comply with, but the air condensers will be set up again as soon as possible, and then capacity tests can be made.

With regard to platinum thermometry, Mr. Matthey supplied the Committee with a further specimen of wire, for which he had made a large stock. This was tested carefully, both at Kew and under Mr. Griffiths' directions, by Mr. Green at Cambridge, and the values found for the constants were as under :

$$R_{100}/R_0=1{\cdot}3892$$
$$\delta=1{\cdot}495\pm{\cdot}005$$

The wire has proved in every way satisfactory, and the money voted this Committee last year (45*l.*) has been spent in purchasing it.

Mr. Matthey, however, is retaining for the present, for the use of the Committee, some more of the wire, and it is, in their opinion, desirable that they should purchase it also. It is essential for the success of the scheme approved by the Committee at their last meeting that they should have a sufficient stock of the wire for a very long period, and they are anxious not to lose the present opportunity of acquiring such a stock.

Expense will also be incurred in the preparation of the mercury standards.

The illness and death during the year of Professor Viriamu Jones have prevented any great progress being made with the ampère balance. Some part of the apparatus, however, has been constructed, and is in Professor Ayrton's hands, and the Committee have good hopes that further progress may be reported shortly.

The Committee desire to put on record their sense of the loss which Physical Science has suffered by the deaths of Professors J. V. Jones and G. F. FitzGerald, who for many years had been members of the Committee, and had contributed in a marked degree to its work; and by that of Professor Rowland, whose redetermination of the absolute value of the B.A. unit was practically the starting-point of the work of the present Committee. Professor Rowland had on more than one occasion been a valued visitor at meetings of the Committee.

A paper by Mr. Skinner on a pyridine voltameter is printed as an appendix. Professor Callendar's paper on the variation of the specific heat of water is closely connected with the work of the Committee.

In conclusion, the Committee recommend that they be reappointed, with a grant of 50*l.*; that Lord Rayleigh be Chairman, and Mr. R. T. Glazebrook Secretary.

APPENDIX.

Note on a Comparison of the Silver deposited in Voltameters containing different Solvents. By S. SKINNER, *M.A., Demonstrator of Experimental Physics, Cambridge.*

In 1892 Schuster and Crossley[1] showed that when the same current is passed through two silver voltameters containing silver nitrate in aqueous solution, one voltameter in a vacuum and the other in air, about 0·1 per cent. more silver was deposited in the vacuum than in air. This result was confirmed by Myers.[2] These results clearly prove that there is an uncertainty in the action of the silver voltameter depending on the presence of air or oxygen, and consequently on the freshness of the solution. Werner[3] found that a silver nitrate solution in pyridine gives by the rise in the boiling-point of the solvent a nearly normal molecular weight for the salt; and Kahlenberg[4] found that the solution was an electrolyte, and could be used in the silver voltameter; but that, contrary to what follows, more silver was deposited from aqueous solution than from pyridine solution by the same current. In the following experiments a comparison has been made of the deposits produced by the

[1] *Proc. R.S.*, 50, p. 344.
[2] *Annalen*, 55, p. 288.
[3] *Zeits. Anorg. Chem.*, 1897, 15, p. 23.
[4] *Journ. Physical Chem.*, 1900, p. 349.

same current in silver voltameters containing aqueous and pyridine solutions of silver nitrate.

The platinum bowls used are those numbered I. and V. in the paper on the Measurement of the Electromotive Force of the Clark Cell[1] by Mr. Glazebrook and myself. The anode for bowl I. was a silver disc, 5 cm. in diameter, hung by a silver rod, and a silver cylinder was used for bowl V. The dimensions of the bowls are given in the paper mentioned above. 100 c.c. of solution was used in each case, and the pyridine solution contained 10 per cent. of silver nitrate, whilst the aqueous solution contained, as usual, 15 per cent. of the salt.

The areas of the exposed surfaces were approximately as follows:—

	Bowl I.	Bowl V.
Cathode surface . .	·75 sq. cm.	67 sq. cm.
Anode surface . .	19·6 sq. cm.	18 sq. cm.

The conditions of current density in the two bowls may be regarded as practically identical.

The deposit of silver from the aqueous solution was crystalline, and the character of the crystals appeared to vary with the current density. The deposit was washed by standing in distilled water for several hours and dried over an alcohol flame. The deposit from the pyridine solution is continuous, and forms a hard coating: it is washed with water in which both pyridine and silver nitrate are soluble. It is sometimes slightly coloured, but on drying becomes white. On further heating over the alcohol flame it develops a pearly lustre, and in this condition it has been weighed.

A Western ampère meter was included in the same circuit, and served to indicate the constancy of the current. The reading of the ampère meter is given in the second column of the table. The variations of the current were very small. In the table the result of every experiment which I have made is given.

Date	Current by Weston Meter	Weight deposited from Pyridine Solution	Weight deposited from Aqueous Solution	Difference Milligrammes	Percentage Difference	Notes
Aug. 15	0·07	·8115	·8105	1·0	·124	
16	0·075	·8695	·8685	1·0	·115	
14	0·13	1·2665	1·2625	4·0	·318	(c)
8	0·253	·7865	·7820	4·5	·575	
21	0·255	2·2795	2·2730	6·5	·30	
6	0·368	1·1390	1·1340	5·0	·44	
12	0·375	·9630	·9600	3·0	·41	(a)
10	0·415	1·4225	1·4200	2·5	·276	(b)
19	0·52	2·0010	1·9982	2·8	·14	
20	1·00	2·0180	2·0155	2·5	·12	
Total deposits.		13·5570	13·5242	32·8	·24	

(a) and (b).—In these two experiments the aqueous solution was in a partial vacuum (8 cm. pressure), and ·1 per cent. has been added to the percentage difference to make them comparable with the other experiments.

(c).—Fresh solutions were used in this experiment, and the same solutions were used on all subsequent dates. A few particles of silver were lost from the aqueous voltameter in this experiment, August 14.

The first result of these experiments is clearly that all the deposits

[1] *Phil. Trans.*, 1892, A.

from the pyridine solutions weigh more than those from the aqueous solutions.

In the measurements of the E.M.F. of the Clark cell by Mr. Glazebrook and myself the same current was sent through two systems of silver voltameters in series, and 15·5123 grammes were deposited in the bowls which received the greater deposits, as against 15·5055 grammes in those which gained the smaller deposits. This gives a mean percentage difference of ·044, which may be compared with the mean percentage difference of ·24 in the present experiments. It is obvious that this difference is of a much higher order, but this difference is a mean of experiments which differ much more between themselves. On that account I think it is better to discuss the experiments in groups. The experiments divide themselves roughly into two groups. There is, first, a group consisting of those in which the current was about ·07 ampère and from ·5 to 1 ampère. This contains the extremes as regards current, and in it the mean percentage difference would be just over ·1 per cent. So that for these values of current the deposit from pyridine would weigh almost the same as Schuster and Crossley found for a vacuum, which, it will be remembered, was ·1 per cent. higher than in air.

The second group consists of those experiments in which the current value lies between ·13 and ·41 ampère, and here the mean percentage difference is much larger, *i.e.*, ·38. Over this range one of the deposits seems to be uncertain, and I think these experiments may be considered to indicate that between these values of current in the given bowls one of the two voltameters is irregular in its action. The character of the silver crystals appeared to be variable, whilst the hard film of silver from the pyridine solution had always the same texture. The aqueous voltameter seemed to work best with the large currents ·5 to 1 ampère when the crystals were small, hard, and closely packed. At the lower values of current the silver crystals were thin, long, and friable. At the lowest value they were again small and hard. One explanation of the variation may be that particles of silver are more easily lost during the washing, when the crystals are of the second character.

Conclusions :—

(1) That Faraday's law holds to within ·24 per cent. in the mean for silver nitrate when dissolved in two different solvents.

(2) That for current values of ·07 and ·5 to 1 ampère in the given bowls the amount of silver deposited from a pyridine solution of silver nitrate is nearly the same as that deposited from an aqueous solution in a vacuum.

(3) That for current values between ·1 and ·5 ampère more silver obtained in the pyridine voltameter than in the aqueous voltameter.

Note on the Variation of the Specific Heat of Water.
By Professor H. L. CALLENDAR, *F.R.S.*

[Ordered by the General Committee to be printed *in extenso.*]

The method adopted for determining the variation of the specific heat of water was described and the apparatus exhibited at the Toronto Meeting of the British Association,[1] and the results up to a temperature of 60° C.

[1] *B.A. Rep.*, 1897.

were given in a preliminary note communicated to Section A at the Dover Meeting.[1] The final results were communicated to the Royal Society in June 1900,[2] and are now in course of publication in the 'Phil. Trans.' The object of the following note is to discuss one or two minor corrections and reductions which have been suggested.

Values below 20°.

At the Dover Meeting of the British Association it was stated that the observations agreed very perfectly on the average with Rowland's from 5° to 35°, but indicated a slightly more rapid change near the freezing-point. This change required further verification, and was not included in the formulæ then suggested. Subsequent observations have confirmed this effect, which may be represented within the limits of probable error by the addition of another term to the formula below 20° C. The formula given in 1899 for the specific heat s at any temperature t between 0° and 60° was as follows:—

$$s = \cdot 9982 + \cdot 0000045\,(t-40)^2 \quad . \quad . \quad . \qquad (1)$$

Below 20° the formula should read:

$$s = \cdot 9982 + \cdot 0000045\,(t-40)^2 - \cdot 0000005\,(t-20)^3 \quad . \qquad (2)$$

This formula agrees with the curve and with the correction to the total heat h of the liquid given in the note in the 'British Association Report,' 1899. Values calculated by these formulæ are given in Table II. in the column headed B.A. 1899.

The quantity actually observed by Rowland was the total heat of the liquid from the starting-point of each experiment. The following table shows the close agreement of his results with this formula:—

TABLE I.—*Values of Total Heat of Water*, 5°–35°.

Temperature.	Formulæ (1) and (2).	Rowland.
°		
5	5·037	5·037
10	10·056	10·058
15	15·065	15·068
20	20·068	20·071
25	25·065	25·067
30	30·060	30·057
35	35·052	35·053

Results above 60°.

In the 'British Association Report,' 1899, Regnault's formula was adopted for the variation above 60°, modified by subtracting a constant quantity ·0056, to make it fit with formula (1) at 60°, and to reconcile his results with those of Reynolds and Moorby. We thus obtain

$$s = 0\cdot 9944 + 0\cdot 00004t + \cdot 0000009t^2 \quad . \quad . \quad . \qquad (3)$$

Subsequently to the Dover Meeting Dr. Barnes succeeded in obtaining

[1] *B.A. Rep.*, 1899. [2] *Proc. R.S.*, 1900.

five or six results at points between 66° and 92°, which are represented within one part in 10,000 by the linear formula

$$s=1+\cdot 00014\,(t-60) \quad . \quad . \quad . \quad . \quad (4)$$

This formula gives a value nearly 1 in 1,000 lower than (3) at 90°, but it cannot be reconciled with Regnault's observations between 110° and 190° C., and it would therefore probably be better to retain (3), since it is likely that the specific heat would increase more rapidly at high temperatures.

Although the actual observations at these higher points agree with formula (4) much more closely than 1 in 1,000 it is conceivable that they might contain a constant error of this order at 90°.

More complicated formulæ are given by Dr. Barnes,[1] but since the whole variation of the specific heat is so small it does not seem worth while to change the simpler formulæ already published in the 'British Association Report,' 1899, which represent the observations equally well.

Comparison with Lüdin.

The results of the observations of Lüdin by the method of mixtures are given in Table II. for comparison. They agree very well below 20°, but show a minimum at 25° C. Above this point they increase rapidly to a maximum at 85° C., which is 1 per cent. greater than the value found by Barnes when expressed in terms of the same unit. This rapid increase may possibly be explained by radiation error from the hot-water supply. The subsequent diminution between 85° and 100° may be due to evaporation of the boiling water on its way to the calorimeter. These errors are peculiar to the method of mixtures, and are completely eliminated in the electrical method. Moreover, the quantity measured in the method of mixtures is not the actual specific heat at the higher limit t, but the mean specific heat between t and the temperature of the calorimeter. The values of the actual specific heat at t, which depend on differentiating the curve of mean specific heat, are thus rendered extremely uncertain near the extremities of the range. The electrical method avoids this uncertainty, since it directly measures the rise of temperature produced by the same quantity of energy at different points of the scale.

Correction for Variation of Temperature Gradient in the Flow-tube.

If E is the difference of electric potential in volts between the ends of the conductor;
C, the current in ampères through it;
J, the number of joules required to raise 1 gramme of water 1° C. at the mean temperature of the experiment;
Q, the water-flow in grammes per second;
θ, the rise of temperature;
$h\theta$, the loss of heat by radiation, &c., in joules per second,

we have the simple equation

$$EC=JQ\theta+h\theta \quad . \quad . \quad . \quad . \quad (5)$$

If we assume that the heat-loss $h\theta$ is the same for two different flows, provided that the electrical current is regulated so as to secure the same

[1] *Proc. R.S.*, 1900.

final rise of temperature θ, we can easily eliminate h and find J. When the flow is large, the heat loss $h\theta$ is a small fraction, 1 or 2 per cent., of the whole. The gradient of temperature in the flow-tube is then nearly constant, but diminishes slightly as the temperature rises, owing to increased rate of loss of heat. With smaller flows this effect increases, as the magnitude of the loss $h\theta$ becomes greater in proportion to the whole. There is therefore a small systematic variation in the temperature distribution when the flow is changed, which may be calculated from the differential equation representing the conditions of heat-loss and supply. The effect can be represented by adding to equation (5) a term $11h^2\theta/25$ JQ, in which the numerical factor 11/25 depends on the relative dimensions of the tubes of the calorimeter employed. At a temperature of 30° C. h is 2 per cent. of JQ for the larger flows, and the correction amounts to only 2 or 3 parts in 10,000. Dr. Barnes observed that the results deduced from the smaller flows differed systematically from those given by the larger flows, but the differences were so small that he thought they might be due to accidental errors of observation or some defect of the method. I find, however, that these small systematic differences are almost exactly accounted for by the correction in question. This is an excellent verification of the accuracy of the work. The importance of the correction arises from the fact that the heat-loss increases nearly as the fourth power of the absolute temperature, and the correction itself increases as the square of the heat-loss. Although practically negligible at ordinary temperatures, it reaches one part in 1,000 at the higher points. The results published in the 'Proc. R.S.,' 1900, must be corrected for this source of error. The corrected values are given in column (1) of Table II.

Reduction to the Hydrogen Scale.

The observations were all taken directly with standard platinum thermometers, and the temperatures were reduced by means of the difference-formula

$$t-pt=1\cdot50t\,(t-100)/10{,}000 \quad . \quad . \quad . \quad (6)$$

This gives a perfectly definite scale of temperature, which agrees very closely, according to the observations of Callendar and Griffiths,[1] with that of the constant-pressure air-thermometer. It is really preferable and express the results in terms of this scale, which has the advantage that it can be reproduced with much greater accuracy than is attainable in gas-thermometry. If, however, we assume that it coincides with the scale of the air-thermometer, it would be desirable to reduce the results to the hydrogen scale, as being a closer approach to the absolute thermodynamic scale.

In making this reduction it would be most natural to assume the well-known formula for the difference between the nitrogen and hydrogen scales given by Chappuis, and quoted by Guillaume and other authorities :

$$t_n-t_h=t(t-100)(+6\cdot318+0\cdot00889t-0\cdot001323t^2)\times10^{-6} \quad . \quad . \quad (7)$$

This has been done by Griffiths,[2] who gives a table of our results so reduced. There are, however, one or two objections to be considered. (1) The formula of Chappuis makes the differences t_n-t_h *negative* between 80° and 100°, so that the correction to the specific heat changes from −2 in 10,000 at 80° to +6 in 10,000 at 100°. Chappuis himself

[1] *Phil. Trans.*, 1890.

considers this impossible, and has recently[1] proposed an emended curve, which would alter the correction by nearly one part in 1,000 at 100°. (2) The experiments of Chappuis refer to the constant-volume nitrogen-thermometer at one metre of mercury initial pressure, whereas the difference-formula is assumed to refer to the constant-pressure air-thermometer at 76 cm. pressure. The correction in the latter case is quite different, so that we should not assume Chappuis' results for the reduction. On the whole we shall probably be nearest the truth if we calculate the correction for the scale of the constant-pressure air-thermometer from the observations of Joule and Thomson[2] by the method which I have explained in 'Proc. Phys. Soc.,' March 1901. It happens that the correction to the results, when calculated in this manner, is very nearly equal and opposite to that already given for the variation of the temperature-gradient in the flow-tube, so that if both corrections are applied the results are practically unchanged. It must be remembered, however, that one of these corrections is certain and obligatory, whereas the other is to a great extent a matter of taste. It would really be more scientific to omit the uncertain reduction to the hydrogen scale.

The value of the difference coefficient 1·50 in formulæ 6 is calculated, assuming the boiling-point of sulphur to be 444°·5, on the scale of the constant-pressure air-thermometer. If we took the boiling-point of sulphur to be 445°·2 (as determined by Harker and Chappuis with a constant-volume nitrogen-thermometer at 560 mm. initial pressure), we should find $d=1{\cdot}54$. This would make a difference of 4 in 10,000 in the values of the specific heat at 0° and 100°. But the correction from the constant-volume nitrogen scale would be much smaller, so that, by a curious coincidence, the final results reduced to the hydrogen scale would be almost identical with those already given.

TABLE II.—*Variation of Specific Heat of Water in terms of a Unit at 20° C.*

Temperature	R.S. 1900 Corrected	Reduced to H Scale	B.A. Report, 1899	Lüdin, 1895
°				
0	1·0080	1·0084	1·0094	1·0084
5	1·0052	1·0055	1·0054	1·0051
10	1·0029	1·0031	1·0027	1·0026
15	1·0011	1·0012	1·0011	1·0009
20	1·0000	1·0000	1·0000	1·0000
25	·9991	·9991	·9992	·9998
30	·9987	·9986	·9987	·9999
35	·9986	·9984	·9983	1·0006
40	·9986	·9984	·9982	1·0017
45	·9988	·9986	·9983	1·0030
50	·9993	·9989	·9987	1·0046
55	·9998	·9994	·9992	1·0063
60	1·0005	1·0000	1·0000	1·0079
65	1·0011	1·0006	1·0008	1·0094
70	1·0018	1·0013	1·0016	1·0109
75	1·0024	1·0020	1·0024	1·0123
80	1·0033	1·0027	1·0033	1·0131
85	1·0040	1·0034	1·0043	1·0137
90	1·0048	1·0041	1·0053	1·0136
95	1·0055	1·0048	1·0063	1·0129
100	1·0062	1·0055	1·0074	1·0117

[1] *Phil. Mag.*, 1900 [2] *Phil. Trans.*, 1862.

Radiation in a Magnetic Field.—Report of the Committee, consisting of the late Professor G. F. FITZGERALD (*Chairman*), Professor W. E. THRIFT (*Secretary*), Professor A. SCHUSTER, Principal O. J. LODGE, Professor S. P. THOMPSON, Dr. GERALD MOLLOY, *and* Dr. W. E. ADENEY.

THE Committee have to refer with feelings of the deepest regret to the death of their Chairman, Professor G. F. FitzGerald, and acknowledge that their work has been much impaired by the loss they have sustained.

That work seemed twofold: in the first place, to obtain specimen prints and enlargements of the negatives left by Preston, in order to consider the advisability of publishing them; in the second place, to study the negatives and measure the separations of the various lines.

Nineteen of these negatives are interesting, viz., ten of iron, five of cadmium and zinc, two of magnesium, one of strontium, and one of nickel, but their value is much lessened because no information is obtainable concerning the corresponding strength of the magnetic field. However, from their examination of the specimen prints and enlargements which they have obtained, the Committee conclude that it would be desirable publish prints of some, at least, of the negatives. They are interesting on account of their priority as photographic records of the effect of a magnetic field upon the spectral lines, and on account of the clearness with which they exhibit the effect, both in its normal and in many anomalous forms; and the information derivable from them would thus become available to all. The Committee, therefore, recommend their publication, and ask for reappointment, with a grant of 15*l.*, in order to carry this recommendation into effect.

The work of measuring the negatives has been confined to preliminary investigations on the degree of accuracy attainable, and to some observations on the iron spectrum. With the instrument used by Sir Robert Ball and Dr. Rambaut for measuring star photographs it was possible by special arrangements to measure, in general, to 0·006 tenth metre. This would imply that the resulting values of $\frac{\lambda^2}{\Delta\lambda}$, for example, $25{\cdot}8 \times 10^6$, are accurate to 0·2 or 0·3. But the calculated values of $\frac{\lambda^2}{\Delta\lambda}$ for the lines, observed so far, show such variety that the verification for iron of the law demonstrated by Preston for cadmium, zinc, and magnesium seems most improbable at present.

Several anomalous lines have been observed, particularly the quintet at 3743·51.

No unaffected lines have been met with; those which are not split up into separate components are much broadened.

Interference and Polarisation of Electric Waves. By Professor Dr. G. QUINCKE.

[Ordered by the General Committee to be printed *in extenso.*]

IN the Physical Laboratory of the University of Heidelberg Dr. August Becker has measured the wave-lengths of electric vibrations in interference-tubes with two branches or in T-shaped tubes of the form which Professor Quincke used for acoustical researches.

The maxima and minima of the waves have been observed by means

of a coherer in air, and in different fluid or solid dielectrics. Through interference-tubes with two branches only those vibrations are transmitted which are parallel to the plane of the branches, and of a wave-length equal to 1·6 the diameter of the tube. Such an interference-tube represents for electric waves a Nicol prism or a coloured glass plate for optical waves. Wave-length or velocity inside the interference-tubes is about $\frac{4}{5}$ of the wave-length or velocity outside in the free air. The ratio of the wave-length in air and in fluids gives $\sqrt{k}$, k being the specific inductive capacity of the fluid.

Seismological Investigations.—Sixth Report of the Committee, consisting of Professor J. W. JUDD (*Chairman*), Mr. J. MILNE (*Secretary*), Lord KELVIN, Professor T. G. BONNEY, Mr. C. V. BOYS, Professor G. H. DARWIN, Mr. HORACE DARWIN, Major L. DARWIN, Professor J. A. EWING, Professor C. G. KNOTT, Professor R. MELDOLA, Mr. R. D. OLDHAM, Professor J. PERRY, Mr. W. E. PLUMMER, Professor J. H. POYNTING, Mr. CLEMENT REID, Mr. NELSON RICHARDSON, *and* Professor H. H. TURNER.

CONTENTS.

I. *On Seismological Stations abroad and in Great Britain.*

SEISMOGRAPHS of the type recommended by the Seismological Investigation Committee of the British Association have been constructed for and in most instances are already established at the following stations :—

*1.	Africa	Cape Town.	*20.	Mauritius . . .	Royal Alfred Observatory.
*2.	„	Cairo.*			
3.	Australia	Melbourne.	21.	Mexico . .	Mexico.
4.	„	Sydney.	22.	New Zealand (2 instruments)	Wellington (2 instruments).
5.	„	Western Australia.	23.		
*6.	Canada	Toronto.	24.	Portugal	Coimbra.
*7.	„	Victoria, B.C.	25.	Russia	Irkutsk.
8.	Ceylon	Colombo.	26.	„	Tiflis.
*9.	England	Shide, Isle of Wight.	27.	„	Taschkent.
*10.	„	Kew.	*28.	Scotland	Edinburgh.
*11.	„	Bidston.			Paisley.
12.	Germany	Strassburg.	*30.	S. America	Cordova.
13.	Honolulu	Hawaii.	31.	„	Arequipa.
*14.	India	Calcutta.	*32.	Spain	San Fernando.
*15.	„	Madras, Kodaikanal.	33.	Syria	Beyrut.
16.	„	„ Jugga Row.	34.	Trinidad.	
*17.	„	Bombay.	35.	U.S. of America	Philadelphia.
*18.	Java	Batavia.	36.		Baltimore.
*19.	Japan	Tokio.			

The last instrument constructed is in charge of Mr. L. Bernacchi, of the ss. 'Discovery.' If possible it is to be used in the Antarctic Regions. Continuous records have been received from stations marked with an asterisk, whilst Mexico, New Zealand, Trinidad, Philadelphia, and Baltimore have sent occasional records.

The last registers issued by the British Association Committee are Circulars Nos. 2 and 3. These refer to Shide, Kew, Toronto, Victoria, B.C., San Fernando, Cairo, Cape Town, Mauritius, Calcutta, Bombay, Kodaikanal, Batavia, and Cordova. These are complete up to the end of December 1900, excepting for Cordova (Circular No. 2), the entries for which end on June 21, 1900.

The instruments now in use at the Shide station are:—

1. A photographic-recording horizontal pendulum oriented North and South. This is the type of instrument similar to those at other stations.

2. A pair of pendulums similar to the above, oriented North-South and East-West. This instrument was kindly presented to your Secretary by Mr. A. F. Yarrow.

3. A pair of horizontal pendulums writing on smoked paper. These have arms 14 inches in length, and each carries a 10 lb. weight.

4. A pair of horizontal pendulums also writing on smoked paper The arms are 9 feet in length, and each weighs about 100 lb. This and instrument No. 3 give open diagrams.

5. A simple spiral spring seismograph for vertical motion. Record photographic.

6. A large balance arranged to show tilting.

Analyses of Records for 1900.

An analysis of the earthquakes recorded during the year 1900, similar in character to that given in the Fifth Report issued by your Committee for the records of the previous year, is in progress. Its length precludes it from appearing in these reports.

On the Approximate Frequency of Earthquakes at different Stations.

In the following table the large numerals to the right of or beneath the name of a given station indicate the actual number of disturbances recorded at that station during given intervals of time. For all stations, excepting three, these intervals are the years 1899 and 1900. The three exceptions are Cairo, for which the interval is the year 1900; Calcutta, from July to December 1900; and Cordova, from January to June 1900. Inasmuch as at all stations, for a variety of reasons, there have been interruptions in the continuity of observations, these time intervals must only be regarded as approximations. As it is difficult in the case of certain minute disturbances to determine whether these have a seismic origin or are due to some other cause, the large numerals are only approximations.

The small numerals to the right or left of a large numeral give the percentage of the earthquakes recorded at the station to which it refers, which are common to the registers of the other stations. For example, out of 210 records at Shide, 58 per cent. of them were also noted at Kew, and

40 per cent. at one or more stations in Europe.[1] These latter refer to Strassburg, Hamburg, Laibach, Trieste, or observatories in Italy.

	Shi	Ke	San Fernando	Toronto	Victoria, B.C.	Cairo	Ma	Bo	Cal	Batavia	Mauritius	Cape Town	Cordova, Argentina	European Stations
Shide	210	58	32	47	49	5	12	23	7	34	19	25	19	40
Kew	54	220	29	35	35	3	9	19	8	24	14	19	20	33
San Fernando	87	84	75	79	75	11	23	48	15	63	36	59	53	69
Toronto	40	34	24	241	56	3	7	16	5	21	14	19	15	29
Victoria, B.C.	40	33	23	55	246	3	9	17	4	25	17	19	17	28
Cairo	18	12	14	15	12	45		14	2	20	18	15	12	14
Madras	22	19	15	18	19	3	115	19	4	17	9	15	0	18
Bombay	90	76	62	69	71	14	36	58	14	65	45	52	23	62
Calcutta			13	14	14	2	7	9	57	18	14	14	—	18
Batavia			21	26	29	4	9	14	9	237	19	18	17	21
Mauritius	46	42	39	47	53	9	13	31	13	54	81	41	14	38
Cape Town	53	47	45	48	50	8		32	10	47	85	98	21	45
Cordova (Argentina)	16	16	16	16	16	7		7	—	23	9	12	43	5

From what has been said it is clear that results indicated by the above table are, when we have at our disposal materials more definite in character, open to modification.

Numerous records, as at Shide (210) and Kew (220), may indicate that in the examination of the record-receiving films, in certain instances, minute disturbances have been wrongly accepted as having a seismic origin. The high number of records accredited to Batavia may partly be accounted for by the fact that at that place there are many local shocks the effects of which have not been appreciable at distant stations. That the percentage of the Shide records noted at other stations is, in all instances but one, greater than the percentage of the Kew records at corresponding stations (see the first two horizontal lines in the table) indicates that either the Kew instrument or the ground on which it rests is less sensitive to seismic influences than the instrument or the ground at Shide. A similar conclusion is arrived at if we inspect the two vertical sets of entries beneath the names of these two stations.

The fewness of the San Fernando and Bombay records, and the large percentage of these which are found at other stations, may indicate that at these stations disturbing influences non-recognisable as seismic but rarely occur. For Cairo and Calcutta not only are the records few in number, but the percentages of these common to other stations are also low. The explanation of this probably rests on the fact that these two stations are installed upon alluvium. At San Fernando and Bombay, where the installations are upon hard materials, although the records are not numerous, the percentages of these recognised at other stations are high. If this is correct we have here the reverse of what occurs in the case of earthquake motion that can be felt, the motion being greatest upon the alluvium, and least upon the harder strata.

The low percentages corresponding to the Cordova records may be accounted for by the supposition that many of its entries refer to shocks

[1] See footnote to p. 47.

which do not reach distant stations. Although a list might be made of earthquakes recorded at the European stations here considered, but not at the thirteen widely separated stations indicated in the above table, an inspection of this table shows the converse to be equally true, there having been many earthquakes recorded in the south of South America, on the east and west of North America, in South Spain, and in Great Britain which have apparently escaped record in Central Europe.

In connection with this subject attention may be drawn to the list of earthquakes on pp. 44–46. As this list has been drawn up with great care, it may be taken for granted that all entries which refer to approximately the same times represent seismic disturbances. The larger of these will have been recorded at distant stations. To determine whether this is true for the smaller records observers are asked to make a close inspection of their photographic traces.

Experiments upon Piers.—At the end of March Professor H. H. Turner, F.R.S., visited Shide, where, in conjunction with your Secretary, he measured the stiffness of various piers employed to carry seismographs. To make a measure of this description a rope was tied round the column to be tested about 2 inches from its top. A spring balance was attached to this, and a pull of from 5 to 30 lb. was exerted, with the result that the column was deflected. These deflections were measured by an astronomical level standing on the column, and in certain instances also by the deflection of the boom of horizontal pendulums. The stiffest column tested was a 12-inch earthenware drain pipe, 3 feet in length. The apparent deflection was $0''\cdot09$ per one-pound pull. A brick column 6 feet in height, and in cross-section 3 feet by 1 foot 6 inches, had per lb. pull a deflection angle in directions parallel to its sides of $0''\cdot192$ and $0''\cdot05$, the latter referring to its greatest width.

II. *On Earthquake Records obtained at Stations on different Geological Formations.*—The records referred to in this note were obtained at Kew, Shide, Bidston, and Edinburgh. The instruments used were Milne horizontal pendulums with photographic recording apparatus. They were similarly installed, and, so far as it has been practical, were kept with similar adjustments. The geological formations at these four stations may be briefly described as follows :—

Kew.—Thick alluvial deposits of the Thames Valley, which in their upper parts at least are saturated with water.

Shide.—Here the pier carrying the instrument rests upon the disintegrated outcrop of beds of chalk which form the east and west backbone of the Isle of Wight. These beds plunge at a steep angle, to rise again as a series of chalk downs to the north of the Solent beyond Portsmouth.

Bidston.—The Observatory at Bidston is situated on New Red sandstone.

Edinburgh.—Blackford Hill, on which the Royal Observatory is situated, is a great sheet of 'felstone' or porphyrite of Palæozoic age.

The records obtained from these stations are as follows :—

II. *Records obtained from similar Horizontal Pendulums at Kew, Shide, Bidston, and Edinburgh.*

A.T. means that the record was obscured by Air Tremors. An asterisk in the first column means that this earthquake was also observed at one or more stations in Europe.

Date	Commencement				Duration				Amplitude			
	Kew	Shide	Bidston	Edinburgh	Kew	Shide	Bidston	Edinburgh	Kew	Shide	Bidston	Edinburgh
1901												
	H. M.	H. M.	H. M.	H. M.	H. M.	H. M.	H. M.	H. M.	MM. "	MM.	MM.	MM. "
			Observations began Jan. 8									
Jan. 7*	0 38·3	0 43·2			2 44	2 30			1·0=0·7	1·5=0·7		
„ 8*	20 0·0	20 26·8	20 6·5		0 46	0 30	0 41		0·6=0·4	0·5=0·2	0·4=0·1	
„ 9	14 26·7	12 0	14 39·5		? 0 4		0 4		0·25		Small	
	15 56·7	15 35	15 56·6				0 5					
	17 7·2	15 50	16 47·0				0 40					
		16 5										
		17 40										
„ 13*	23 2·3	22 7·0 ?	22 57·7	Lamp out	0 50	0 55	1 15		0·5=0·38	0·75=0·37	0·35=0·2	
„ 14			20 23·0									
						0 3				0·5=0·23		
„ 17*		?19 31 0	11 7			0 11					Small	
„ 18*	4 56·8	4 35·0 ?	4 56·6	4 57·2	1 23	1 10	1 12	0 40	3·1=2·3	3·5=1·6	1·6=0·48	2·9=1·29
„ 20	14 31·0		14 30		0 5		0 7		0·25		Small	
„ 21		17·0 to 18·0	17 47·5			1 0	0 39			0·25	0·25=0·1	
„ 22*	2 35·5	2 34·9	2 36·5		0 24	0 25	0 30			0·25	0·25=0·1	
„ 24	? 18 56	A.T.	19 30 A.T.		? 1 4		2 0					
„ 25		19 10·0	19 45			0 25	?			0·25	Small	

	7 11·0	6 29·5	6 48·0	5 44	0 8	0 25	0 27	0 55		0·25	0·25 = 0·1	Small
				6 39								
Feb. 1	10 29·6				0 7				0·25			
„ 7*		14·30	14 30	14 29		0 5	1 20	0 1				0·25 = 0·11
				14 54			At intervals	0 2		0·25	Small	0·25 = 0·11
„ 11				3 29·5				0 4				0·2 = 0·09
„ 14		17 29	5 43·4			0 10	0 11			0·5 = 0·23	Small	0·5 = 0·22
		23 47	17 33·5	17 38·5		0 7	0 8	0 2·5		0·5 = 0·23	„	
„ 15*	8 43·0	8 29·1	8 39·5	8 38·0	0 27	1 0	0 31	0 50	0·25	0·5 = 0·23	1·3 = 0·44	0·5 = 0·22
„ 16		A.T.	2 20·6				0 14				0·5 = 0·12	
„ 17*			23 58·2				0 31				0·4 = 0·10	
„ 20*	10 51·5	A.T.	10 4·1	10 59·5	0 37		1 54	0 34	0·4 = 0·29		0·5 = 0·18	0·25 = 0·11
„ 26	19 10·5			5 0								
				5 47	3 8				0·5 = 0·38			Small
„ 27*	19 34·0	1·0 abt.	0 45·0		0 56		0 20			0·25	Small	
Mar. 1		A.T.		10 6·5								Small
				18 0·0								
„ 2	12 0·6		12 1·0		0 15		0 28				slight	
„ 3	8 17·5	8 26·2?	8 17·0	8 6·0	0 25	0 10	0 21	0 50	0·5 = 0·4	0·5 = 0·23	0·3 = 0·1	1·0 = 0·44
„ 3	17 31·7				0 5							
	19 6·5											
„ 4		16 45·6	17 15·0	17 34·0		1 [illegible]	0 15	0 3		0·25	Line thickens	Small
„ 5*				9 57·5				0 4				Small
	?11 1·5	11 3·5	10 55·3	11 7·0	?1′ 44	1 40	1 31	1 46	1·0 = 0·80	1·25 = 0·58	1·3 = 0·54	1·75 = 0·77
			11 5·3									
„ 11		21 23·3		21 39·0		0 26?		0 18		0·25		1·0 = 0·44
„ 16*	12 12·2	12 14·1	12 5·2	12 14·0	1 35	1 40	1 21	1 43	2·0 = 1·66	2·5 = 1·17	1·8 = 0·61	1·75 = 0·77
„ 18			16 30·0				1 0				Slight; perhaps A.T.	
„ 19*	0 11·6	0 2·8	0 7·7	0 12·0	1 0	1 5	1 10	0 49	0·4 = 0·30	0·5 = 0·23	0·6 = 0·28	0·5 = 0·22
		20 45·0 to	21 28·0				0 12				Slight	
		22 15·0										
„ 23*	14 55·6	14 41·7	14 33·7	14 52·0	0 35	1 5	1 5	0 56	0·5 = 0·4	0·5 = 0·23	0·5 = 0·19	0·5 = 0·22
„ 25*	11 47·4	11 48·8	11 48·0		0 44	0 8?	?		1·0 = 0·8	0·25	? A.T.	
„ 28*		18 28·2	19 0·2	18 30·0		0 10	1 0	0 10		0·5 = 0·23	? A.T.*	Small

Records obtained from similar Horizontal Pendulums at Kew, Shide, Bidston, and Edinburgh—continued.

Date	Commencement				Duration				Amplitude			
	Kew	Shide	Bidston	Edinburgh	Kew	Shide	Bidston	Edinburgh	Kew	Shide	Bidston	Edinburgh
	H. M.	H. M.	H. M.	H. M.	H. M.	H. M.	H. M.	H. M.	MM. ″	MM. ″	MM. ″	MM. ″
Mar. 31*	7 14·7	7 13·8	Lamp out	7 19·5	0 49	1 0		0 29	3·0=2·4	2·0=0·94		4·0=1·77
April 2*		16 59·5		4 48·0		0 10				0·25		Numerous
				to								A.T.'s.
				17 8·0								
„ 3*		16 3·3				0 7				0·25		
						or						
		8 5				0 18						
„ 4*		8 43	9 35·0	0 0·0			0 33			0·25	0·2=0·07	Numerous
		9 2		to								A.T.'s.
				11 0·0								
„ 5*	23 13·4	23 21·0	22 27·3	23 18·0	3 30	3 35	4 8	3 43	4·8=3·94	8·5=4·0	7·6=2·58	5·0=2·22
		12 34·3	13 0·5			1 35	0 23			0·25	Slight	
		14 9·6										
„ 6*	21 16·9	21 17·9	21 19·9	21 40·0	1 22	1 55	1 34	1 17	0·8=0·64	1·5=0·70	2·6=0·88	
„ 7	23 42·2	23 41·4	23 49·0	23 49·0	0 19	1 49	0 19		0·4=0·3	0·5=0·23	Small	Very small
„ 9				22 10·0				0 3				0·25=0·11
*	22 20·0	22 15·6	22 10·8	22 19·0	0 8	0 30	0 11	0 3		0·5=0·23	Small	0·25=0·11
„ 12		18 24·9?										
„ 18*			3 0·6	3 57·5			1 27	0 18			0·5=0·2	Very small
		14 39·3	5 0·0			0 5			0·5=0·4	0·5=0·23	Line	
											thickens	
„ 26	19 33·0				2 21				0·4=0·3			
„ 27*	4 34?	A.T.	4 22·8	4 37·0	0 5?		0 39	0 20			0·5=0·18	0·5=0·22
	8 39·0 to											
	8 4·5											
„ 30	8 4·5				0 6							

Earthquake Frequency.—As it is possible that an entry which only refers to one station and does not appear to have been noticed in Europe may not have had a seismic origin, in the summation of the above lists such entries have been omitted. Adopting this precaution, the number of earthquake records obtained at the different stations are as follows :—

Bidston, 33 or 36 ; Shide, 31 or 33 ; Kew, 26 ; Edinburgh, 21.[1]

Earthquake Duration.—In summing up the total number of minutes during which the pendulums have been moved, only the fourteen earthquakes are considered which were recorded or might have been recorded at the four stations. The results in minutes are as follows :—Bidston, 919 ; Shide, 887 ; Edinburgh, 825 ; Kew, 761.

Accuracy in the Observation of Times of Commencements.—The greatest possible difference in time we should consider likely to exist between the commencement of movement for a given earthquake at two stations would be for disturbances travelling in a northerly or southerly direction between Shide or Kew and Edinburgh, and this could not be expected to exceed five minutes. Between Shide and Kew there might be a difference of one minute, whilst between Bidston and the remaining stations the differences should not exceed two and a half minutes. In the columns relating to these differences the zero indicates the station at which motion was first recorded. The minutes which elapsed before the same disturbance was noted at the remaining stations are indicated by numerals to the right or left of the zero.

A minus sign following one of these numerals indicates that the time interval exceeds the expected interval, whilst a plus sign indicates that the numeral is a possible quantity. For the second entry the four minus signs indicate that there are not even two entries which are comparable. In the third entry for February 15, Edinburgh and Bidston, like Edinburgh and Kew, are possible figures, and therefore these three stations are credited with a plus.

Date	Duration in Mins.				Amplitudes								Duration of P.T.'s				Differences in time of Commencements			
	Kew	Shide.	Bidston	Edinburgh	Kew		Shide		Bidston		Edinburgh		Kew	Shide	Bidston	Edinburgh	Kew	Shide	Bidston	Edinburgh
1901					MM.	"	MM.	"	MM.	"	MM.	"	Min.	Min.	Min.	Min.	Min.	Min.	Min.	Min.
Jan. 18	83	70	72	40	3·1	2·3	3·5	1·6	1·6	0·5	2·9	1·3	25	23	19	18	0	?	0	1
" 22	24	25	30	0																
" 30	8	25	27	55													41−	0−	18−	9−
Feb. 14	0	7	8	8																
" 15	27	60	31	50	0·3	0·2	0·5	0·2	1·3	0·4	0·5	0·2	7 ?	18	15	10	14+	0−	10+	9+
March 3	25	10	21	50																
" 5	104?	100	91	106	1·0	0·8	1·3	0·6	1·3	0·5	1·7	0·8	30	30	25	29	6+	8+	0−	12+
" 16	95	100	81	103	2·0	1·7	2·5	1·2	1·8	0·6	1·7	0·8	24	22	27	25	7+	9+	0−	9+
" 19	60	65	70	49	0·4	0·3	0·5	0·2	0·6	0·3	0·5	0·2	29 ?	41	30	0 ?	8+	0−	4−	9+
" 23	35	65	65	56	0·5	0·4	0·5	0·2	0·5	0·2	0·5	0·2	5 ?	?	23	2	21+	7−	0−	18+
" 28	0	10	60	10																
April 5	210	215	220 or 248	223	4·8	3·9	8·5	4·0	7·6	2·6	5·0	2·2	60	73	80	74	46+	54+	0−	51+
" 6	82	105	94	77													0+	1+	2+	23−
" 7																	1+	0+	8+	8+
" 9	8	30	11	8													12−	5+	0+	0+

[1] 74 per cent. of the Shide records are common to Kew, and 88 per cent. of the Kew records are common to Shide. See pp. 42, 43.

Proceeding in this manner, we find that out of the eleven earthquakes considered, the number of commencements which may approximate to correctness are as follows :—Kew, 8 ; Edinburgh, 8 ; Shide, 6 ; Bidston, 4.

In considering these results it must be remembered that the earthquakes considered are for the most part small, and the difficulty of accurately analysing a small seismogram is greater than when analysing one that is large.

Amplitudes.—For seven earthquakes the sum of the amplitudes of motion reckoned in millimetres at the four stations are as follows :—Shide, 17·3 ; Bidston, 14·7 ; Edinburgh, 12·8 ; Kew, 12·1. Assuming that these displacements represent tiltings, which is improbable, the results are as follows :—Kew, 9″·8 ; Shide, 8″·0 ; Edinburgh, 5″·7 ; Bidston, 5″·1.

The following four figures are sketches made from seismograms obtained on the specified dates at Kew, Shide, Bidston, and Edinburgh. The figures following the letter S indicate the number of millimetres equivalent to one hour :—

FIG. 1. January 18, 1901.

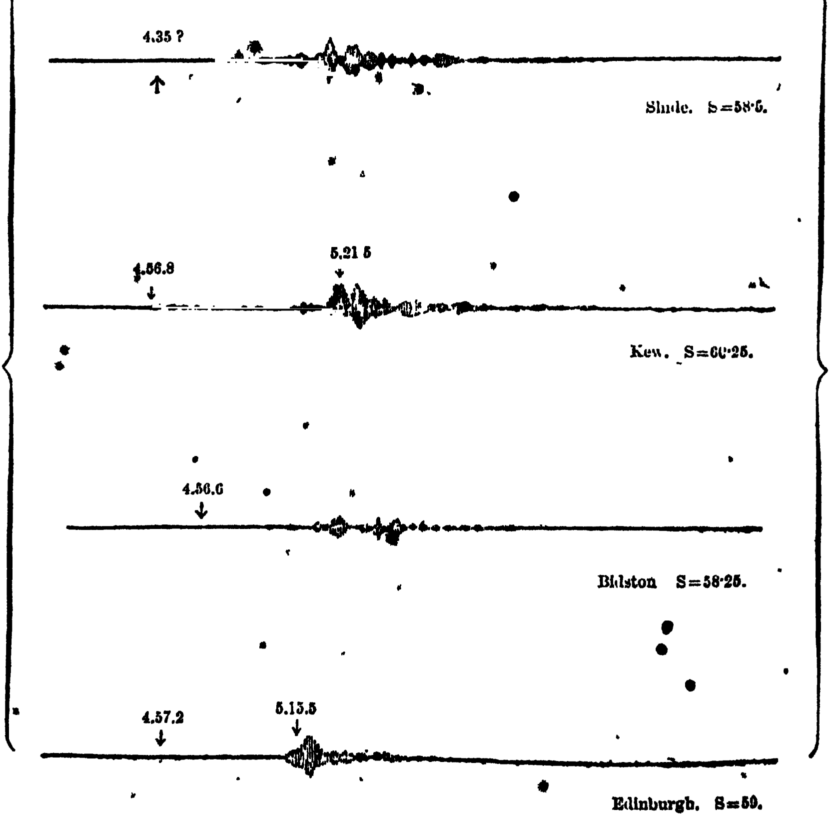


FIG. 2. March 5, 1901.

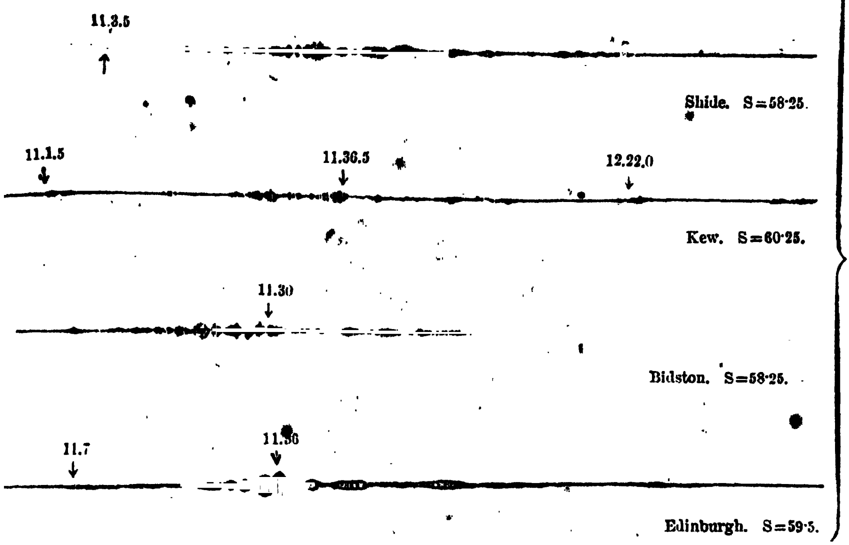
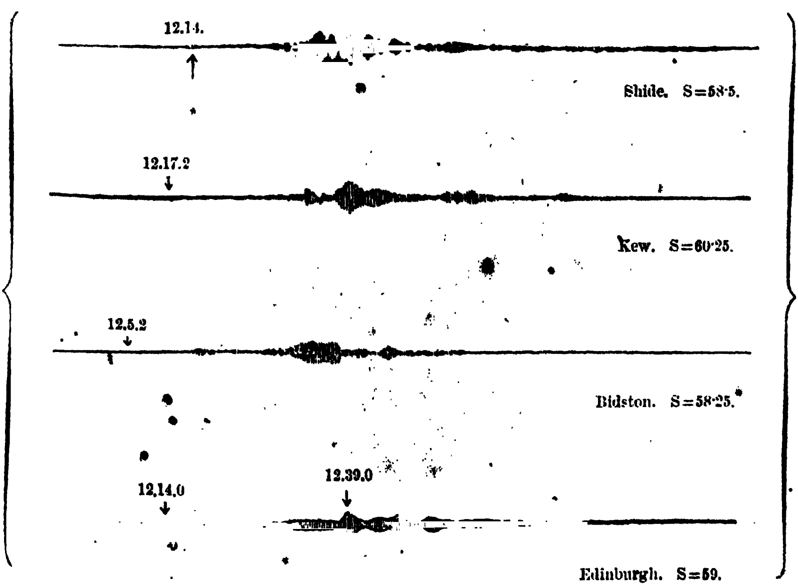


FIG. 3. March 16, 1901.



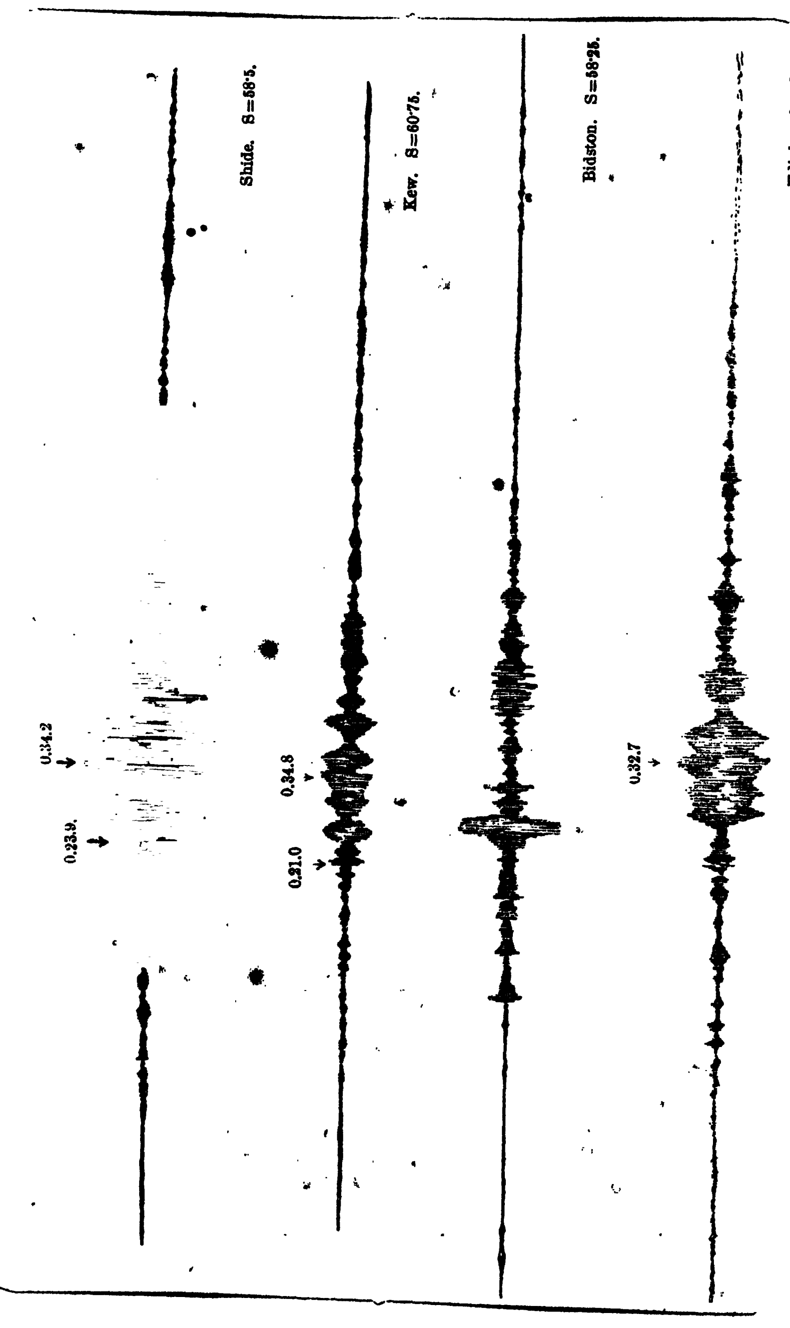


FIG. 4. April 5–6, 1901.

III. *On the Records from two similar Seismographs at Kew. From the National Physical Laboratory.* By CHARLES CHREE.

A Milne seismograph, No. 31, intended for Coimbra, was set up for examination at the National Physical Laboratory on October 30, 1900, its pendulum being at the same level and having the same orientation as that of the seismograph No. 9 belonging to the Laboratory. The points of suspension of the two pendulums were about 11 feet apart. At first the supports of No. 31 rested simply on the stone floor, while those of No. 9 passed through the floor down to a cement bed. After a month's trial, however, the seismographs were interchanged, with a view to eliminating the difference, if any, between the supports. The instruments were adjusted to nearly the same sensitiveness (assuming identity of gauge); they had very approximately the same period and the same rate of subsidence of artificially produced vibrations.

Seven considerable earth tremors were recorded by both instruments. In the four largest the times of commencement of the 'preliminary tremors' shown by the two traces were in excellent agreement, no difference exceeding 0·2 minute. In the other three cases the apparent times differed by from 1·7 to 4·6 minutes, the difference being greatest for the smallest tremors. The times of commencement of the large movements agreed better than those of the preliminary tremors.

As will be seen by a comparison of figs. 5 and 6, there were conspicuous differences in details in the records from the two instruments. This, presumably, is mainly due to the supports. The instrument standing on the floor had, as a rule, a lessened amplitude of vibration, the reduction averaging some 30 per cent. There were, however, not infrequent exceptions

FIG. 5. December 25, 1900.

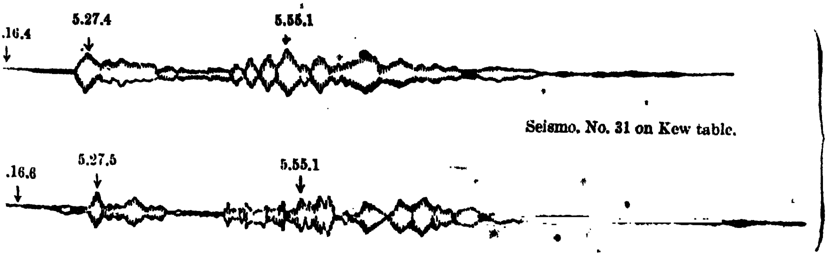
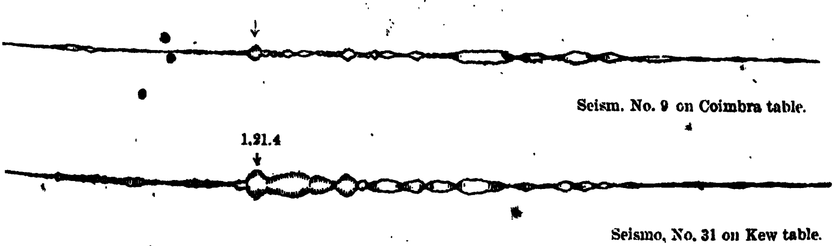


FIG. 6. January 7, 1901.



to the general rule. After allowing for the supports, a small difference still remained between the instruments, the mean apparent amplitude of disturbed movements being some 10 per cent. greater for No. 31 than for No. 9.

During the comparison the observer, Mr. Constable, noticed that on certain days of high wind the trace from the seismograph standing on the floor showed numerous small movements, many possessing distinct asymmetry. Further investigation showed that these undoubtedly arose from vibrations set up in the building by the gusts of wind. Minuter examination showed that the phenomenon also occurred, though to a much smaller extent, in the traces from the seismograph on the cement bed. Wind is thus clearly a cause of not infrequent tiny movements, whose source had hitherto escaped detection.

IV. *Movements of Horizontal Pendulums in relation to Barometric Pressure.*

For many years it has been recognised that there is a relationship between the movements of horizontal pendulums and fluctuations in barometric pressure.[1]

An important and apparently practical addition to our knowledge on this subject has recently been made by Mr. F. Napier Denison, of Victoria, B.C., in a contribution to the Royal Meteorological Society, entitled 'The Seismograph as a Sensitive Barometer.' The instrument referred to is the one adopted by the British Association. Briefly stated, Mr. Denison's conclusion is that the pendulum swings towards the area of greatest barometric pressure. For example, it has been found that when a storm area is approaching from the westward the boom of the pendulum moves steadily to the eastward, and this often occurs eighteen to twenty-four hours before the local barometer begins to fall. On the contrary, should there be an important high area to the West, the pendulum will swing in that direction before it is possible to ascertain the position of such an area on the current weather charts.

As partial confirmation of Mr. Denison's observation, it may be mentioned that a gradual but decided movement of the Shide pendulum towards the West precedes stormy weather, whilst in the Report for 1895 referred to above there are tables showing a close relationship between displacements of pendulums in Tokio and the barometric gradients at that place.

V. *An Attempt to Detect and Measure any Relative Movement of the Strata at the Ridgeway Fault, near Upway, Dorsetshire. Second Report by* Horace Darwin, *June* 1901.

Many of the early readings have been found to be of no value, because water had got into the vessels containing the oil and had blocked its free passage through the pipe; this difficulty has, we hope, been overcome by making the covers of the vessels more completely watertight.

[1] See Reports on 'Earthquake and Volcanic Phenomena,' issued by the British Association in 1883, 1885, 1887, 1888, 1892, 1893, 1895, 1896.

For a theoretical discussion of this subject see 'Applications of Physics and Mathematics to Seismology,' by Dr. C. Chree, *Phil. Mag.*, March 1897, p. 185.

No slip of the Fault has been detected at present; but we should hardly expect a definite result during the short time in which the apparatus has been in working order.

The results obtained so far have been of use in pointing out the difficulties to be overcome and the various defects of the instrument. The movement of the ground caused by slight earthquakes and earth-tilts is one of these difficulties, and our experiment on April 24 brought this to light in a very striking manner. The instrument was placed at the station SS. at the south end of the pipe,[1] and readings were taken every few minutes from 1 to 3 P.M. These readings give the relative movement of a fixed point in the strata and the surface of the oil. The movement was most irregular, and during that time the maximum displacement was about 0·3 mm. This can only mean that a line passing through fixed points in the rock was constantly changing its angle with the horizon; and that the oil was always flowing backwards and forwards in its attempt to remain level. At about 1.40 P.M. the value of the readings reached a minimum, and then began to increase, showing that the angular movement of the strata changed its direction at this time. If we assume that the oil was level when the two readings were taken which differed by about 0·3 mm., it shows that the rock tilted through an angle of about six and a half seconds.

No doubt there was an exceptionally large movement due to slight earthquakes and earth-tilts during the time that these observations were being taken, as Mr. J. Milne tells me that his large pendulum at Shide, Isle of Wight, was swinging regularly, and that this is supposed to be due to earth pulsations.

A telegram from Rome appeared in the daily papers reporting a slight earthquake on April 24 at 3.30 P.M. at Lisbon, and a severe shock at 4.30 P.M. in Algarve, near Lisbon. (4.30 P.M. at Lisbon is 5.7 Greenwich time.)

A note appeared in 'Nature' of July 18, 1901, saying that an account of the earthquake of April 24 in the neighbourhood of Palombara Sabina is given by Dr. Luigi Palazzo in the 'Atti dei Lincei,' x. 9. He thinks it probable that the epicentre was at a sulphur spring about a kilometre distant from Cretone, and that the origin of the shock was in the strata from which the spring arises, at a comparatively small depth. Considerable damage was done at Cretone. The shock was registered at the Central Meteorological Office at about 15h. 20m. 25s. Italian time: this is 2h. 20m. 25s. P.M. Greenwich time.

Mr. Rollo Russell noticed an unusual agitation of the sea at Bournemouth on April 24 at 7.50 A.M., and between 12 and 1 P.M. There was also an exceptionally large wave soon after 3 o'clock.[2]

Mr. C. Davison[3] thinks that the disturbances may have been due to the firing of heavy guns. The disturbances were noticed in South Devon and Guernsey as well as at Bournemouth.

The movement of the earth on April 24 was no doubt exceptionally large, but observations at other times lead me to think that such movements, due to slight earthquakes and earth-tilts, take place very frequently,

[1] A lead pipe connects four vessels, which contain oil; they are in a straight line at right angles to the Fault; two of them are on each side of it at four and a half and nine metres from it.

[2] See *Nature*, May 2, 1901.

[3] *Nature*, June 6, 1901.

and these are sufficiently large to make the last two figures in the delicate micrometer measurements almost useless.

I hope to reduce this motion of the oil by making the holes through which it enters and leaves the vessels sufficiently small to damp the oscillatory movement without preventing the oil finding its own level.

A similar instrument fixed to the rock at a place where there is no Fault would give a delicate and accurate method of measuring these slow earth-tilts.

Tables of Certain Mathematical Functions.—Report of the Committee, consisting of Lord KELVIN (*Chairman*), Lieutenant-Colonel ALLAN CUNNINGHAM, *R.E.* (*Secretary*), Dr. J. W. L. GLAISHER, Professor A. G. GREENHILL, Professor W. M. HICKS, Professor A. LODGE, *and* Major P. A. MACMAHON, *R.A.*, *appointed for calculating Tables of Certain Mathematical Functions, and, if necessary, for taking steps to carry out the calculations, and to publish the results in an accessible form.*

THE printing of the 'Binary Canon' was finished at end of last year. The work, as printed off, has been read again with the MS.; a list of the few misprints discovered has been issued with the volume. The edition is 250 copies, of which 100 have been bound. Arrangements have been made with Messrs. Taylor & Francis, of Red Lion Court, Fleet Street, for publication on the usual terms: the sale price will be 15*s*. About thirty-six presentation copies have been given away to various public bodies, to reviewers, and to those concerned in the work itself. The whole of the grants received (75*l*. from the British Association and 60*l*. from the Royal Society of London), total 135*l*., has been expended.

The Committee wish now to recommend that a large set of *new* tables of *Quadratic Partitions*, prepared by Colonel A. Cunningham (for the checking of which a grant of 30*l*. has already been made by the Royal Society of London), should be published by the British Association, and hereby apply for a grant of 80*l*. for the same.

Meteorological Observations on Ben Nevis.—Report of the Committee, consisting of Lord M'LAREN, Professor A. CRUM BROWN (*Secretary*), Sir JOHN MURRAY, Professor R. COPELAND, *and* Dr. ALEXANDER BUCHAN. (*Drawn up by* Dr. BUCHAN.)

THE Committee are appointed for the purpose of co-operating with the Scottish Meteorological Society in making meteorological observations at the two Ben Nevis Observatories.

The hourly eye observations, made by night as well as by day, have been regularly made by Mr. Angus Rankin, the superintendent and his assistants.

The health of the observers has continued good since last report, with the exception of Mr. Rankin, who has not yet quite recovered from the two severe attacks of influenza he has had. The directors desire to express their cordial thanks to Messrs. W. Gentle, R. C. Marshall, and T. Affleck for the invaluable services they rendered last summer as volunteer observers, thus rendering it possible to give the members of the staff the rest they need from their arduous work.

The principal results of the observations made at the two observatories during 1900 are detailed in Table I.

TABLE I.

1900	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
						Mean Pressure in Inches.							
Ben Nevis Observatory	25·160	24·918	25·417	25·268	25·349	25·386	25·450	25·460	25·475	25·247	25·123	25·041	25·271
Fort William	29·765	29·545	30·087	29·843	29·907	29·859	29·925	29·948	30·004		29·685	29·592	29·83
Differences .												4·551	
						Mean Temperatures.							
Ben Nevis Observatory	24·3	18·9	2·4	29·0	32·5	41·8	42·3	40·8	39·7	30·4	28·8	28·4	31·6
Fort William	40·1	33·3	·9	44·9	49·4	56·6	57·4	56·4	53·4	45·8	42·4	43·4	46·8
Differences .	15·8	14·4	·5	15·9	16·9	14·8	15·1	15·6	13·7	15·4	13·6	15·0	15·2
						Extremes of Temperature, Maxima.							
Ben Nevis Observatory	35·8	31·4	37·0	45·2	47·0	55·2	54·0	61·0	59·4	44·0	41·5	40·0	61·0
Fort William	52·4	49·5	52·0	67·5	68·6	79·0	71·3	76·1	70·0	63·9	58·0	58·1	79·0
Differences .	16·6	17·9	15·0	22·3	21·6	23·8	17·3	15·1	10·6	19·9	16·5	18·1	23·8
						Extremes of Temperature, Minima.							
Ben Nevis Observatory	15·0	6·0	9·3	16·2	19·8	32·8	30·3	28·7	24·8	19·4	18·6	18·5	6·0
Fort William	29·4	10·0	23·0	30·2	34·7	41·7	37·8	41·0	34·0	27·6	28·1	28·9	10·0
Differences	14·4	4·0	13·7	14·0	14·9	8·9	7·5	12·3	9·2	8·2	9·5	10·4	4·0
						Rainfall, in Inches.							
Ben Nevis Observatory	35·32	7·75	3·84	20·22	14·76	6·97	13·12	11·85	16·96	20·93	10·28	48·34	210·34
Fort William	9·99	3·26	0·64	5·87	6·04	4·40	4·51	6·06	7·40	8·80	4·37	20·85	82·19
Differences .	25·33	4·49	3·20	14·35	8·72	2·57	8·61	5·79	9·56	12·13	5·91	27·49	128·15
						Number of Days 1 in. or more fell.							
Ben Nevis Observatory	13	2	1	9	5	0	1	5	6	7	2	18	
Fort William	2	0	0	0	2	0	0	2	2	1	0	6	15
Differences .	11	2	1	9	3	0	1	3	4	6	2	12	54
						Number of Days 0·01 in. or more fell.							
Ben Nevis Observatory	30	20	15	21	20	21	28	18	23	26	24	30	276
Fort William	28	17	10	22	18	17	24	16	19	24	20	31	
Differences .	2	3	5	+1	2	4	4	2	4	2	4	+1	
						Mean Rainband (scale 0–8).							
Ben Nevis Observatory	—	1·1	1·6	—	—	3·1	2·9	3·2	2·5	—	1·6	1·9	
Fort William	3·7	3·0	2·7	3·1	3·6	4·0	4·8	4·1	4·0	3·8	3·6	4·0	3·7
Differences	—	—	—	—	—	—	—	—	—	—	—	—	
						Number of Hours of Bright Sunshine.							
Ben Nevis Observatory	4	34	103	80	98	139	48	92	75	24	17	4	718
Fort William	15	52	119	121	145	182	97	139	86	59	24	1	1,040
Differences .	11	18	16	41	47	43	49	47	11	35	7	+3	322
						Mean Hourly Velocity of Wind, in Miles.							
Ben Nevis Observatory	18	19	9	10	14	11	11				12		
						Percentage of Cloud.							
Ben Nevis Observatory	96	80	70	70	82	79	93	84	78	90	89	97	84
Fort William	84	72	64	68	75	72	88	72	70	63	66	86	73
Differences .	12	8	6	2	7	7	5	12	8	27	23	11	11

This table shows for 1900 the mean monthly and extreme temperature

and pressure; the amounts of rainfall, the number of days of rainfall, and days on which it equalled or exceeded one inch; the hours of sunshine; the mean percentage of cloud; the mean rainband; and the mean velocity in miles per hour of the wind at the top of the mountain. The mean barometric pressures at Fort William are reduced to 32° and sea level, but those at Ben Nevis Observatory to 32° only.

At Fort William the mean atmospheric pressure was 29·831 inches, or 0·026 inch under the average. The mean at the top was 25·275 inches, or 0·031 under the average. The mean difference for the two observatories was 4·556 inches. At the top the absolutely highest pressure for the year was 25·974 inches in March, this being the highest hitherto recorded in March, and the lowest 23·972 inches in December; and at Fort William the highest was 30·687 inches, and the lowest 28·411 inches in the same months, the differences being respectively 2·002 inches and 2·276 inches.

The deviations of the mean temperatures of the months from their respective averages are shown in Table II.:—

TABLE II.

	Fort William.	Top of Ben Nevis.		Fort William.	Top of Ben Nevis.
	°	°		°	°
January	+1·0	+0·3	July	+0·7	+1·6
February	−5·0	−5·0	August	0·0	+0·4
March	−2·0	−1·2	September	+0·4	+1·8
April	−0·2	+1·0	October	−0·8	−1·2
May	−0·7	−0·5	November	−0·4	0·0
June	+1·2	+2·5	December	+3·8	+3·2

February was the coldest month, the temperature at both observatories being 5°·0 under the average. In this month south westerly winds were six days short of their average prevalence, and northerly winds four days in excess. Hence the unusually low temperature which was equally felt both at the foot and top of Ben Nevis. On the other hand, temperature was above the average in the four months from June to September, the excess 1°·6 at the top of Ben Nevis, but only 0°·6 at Fort William, the difference being due to the frequent occurrence of the anticyclonic type of weather during the summer of 1900. The absolutely highest temperature for the year at Fort William was 79°·0 on June 13, and at the top 61°·0 on August 13; and the lowest at Fort William 10°·0 on February 10 and 12, and at the top 6°·0 on February 7.

In Table III. are given for each month the lowest observed hygrometric readings at the top of Ben Nevis:—

TABLE III.

1900	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Dry Bulb	24°·0	12°·9	26°·5	29°·2	36°·8	50°·5	49°·8	53°·0	58°·1	25°·2	27°·0	24°·7
Wet Bulb	20·1	9·2	19·7	25·1	30·2	40·2	39·9	41·0	41·2	22·0	21·1	22·1
Dew-point	−3·0	−19·7	−12·9	10·8	20·8	29·9	29·4	29·0	26·0	4·7	−6·0	7·4
Elastic Force	·038	·018	·023	·070	·112	·166	·162	·160	·141	·054	·032	·060
Relative Humidity [Sat. = 100]	29	23	16	44	51	45	46	39	29	40	22	45
Day of Month	10	11	4	27	16	3	10	15	13	16	18	4
Hour of Day	23	23	1	20	8	17	20	8	16	6	2	7

Of these relative humidities the lowest, 16, occurred on March 4 with a dew-point of $-12^{\circ}\cdot9$. The lowest dew point, $-19^{\circ}\cdot7$, occurred on February 11, the dry bulb being $12^{\circ}\cdot9$ and the wet bulb $9^{\circ}\cdot2$. A marked feature of the table is the singularly high minimum humidities in April, May, June, July, and December.

The rainfall for the year at the top was 210·34 inches, being 52·61 inches, or 33 per cent., above the average. This large rainfall has been exceeded only by that of 1898, which amounted to 240·05 inches. The December amount, 48·34 inches, is the largest monthly fall yet recorded at the Ben Nevis Observatory. The following are the four wettest months of the year :—

	Inches
December	48·34
January	35·32
October	20·93
April	20·22
Total	124·81 in four months.

Taking Scotland as a whole, the year 1900 was one of the wettest yet recorded, and has been only exceeded by the rainfall of 1872. Exceptionally heavy daily rainfalls were of frequent occurrence, the two heaviest being 6·81 inches on January 22, and 5·41 inches on December 8. At Fort William the annual rainfall was 82·19 inches, being 5·28 inches, or 7 per cent., above the average. The largest monthly amount was 20·85 inches in December, accompanying the extraordinary prevalence of south-westerly winds during the month.

At the top of Ben Nevis the number of rainy days was 276, and at Fort William 246. At the top the maximum monthly was 30 days in January and December, and at Fort William 31 days in December and 28 days in January. In March there were only 15 rainy days at the top and 10 days at Fort William. During the year the number of days on which 1 inch of rain or more fell at the top was 69, whereas at Fort William the number of days was only 15.

The sunshine recorder on Ben Nevis showed 718 hours out of a possible of 4,470 hours, or 16 per cent. of the possible sunshine. The average of the past 17 years being 747 hours, the sunshine of 1900 was 29 hours under the average. The two maximum months are June, 139 hours, and March, 103 hours, and the two minimum months January and December, with 4 hours each. At Fort William the number of hours was 1,040. This is lower than any recorded since these observations began to be made, except in 1896, when the number was 1,036 hours. The maximum, 182, was recorded in June, and the minimum, 1 hour only, in December. This is the lowest minimum yet recorded, but the same low minimum, 1 hour, was also recorded at the top for December 1883. In the three summer months, June, July, and August, of 1899 the hours of sunshine at the top were 425, and at Fort William 488 ; but in the same months of 1900 these were respectively only 279 and 418.

At the Ben Nevis Observatory the mean percentage of cloud was 84, and at Fort William 73, both being very nearly the average. At the top the high mean percentages of 97 in December and 96 in January were observed ; and at Fort William 88 per cent. in July and 86 in December.

Auroras were observed only once, viz., March 2. This is in accordance with the number of sunspots being near the minimum at this time.

St. Elmo's Fire was seen on January 19, 20 ; February 18 ; June 30 ; and July 24.

Zodiacal Light :—Not observed during the year.

Thunder and Lightning :—June 11, 12, 13, 20, 21.

Lightning only :—December 13.

Solar Halos :—March 23 ; April 1 ; June 21 ; September 26.

Lunar Halos :—February 7, 9 ; March 17, 18, 19 ; July 13 ; October 3, 30 ; November 8 ; December 3, 4.

During the past year much of Dr. Buchan's time has been occupied in a larger investigation than has hitherto been attempted of the fogs and of the storms of winds round the Scottish coasts. These two distinct inquiries are based on the observations made at the sixty-five Scottish lighthouses night and day down to December 1900.

As regards the fogs, the results show the mean monthly and annual number which have occurred at each of the sixty-five lighthouses from 1880 to 1900, the number of hours fog has prevailed during these twenty years, and the mean number of hours the fog on its occurrence lasts at each place. As regards storms of wind, similar results have been worked out for the twenty years ending 1900.

Now as regards weather forecasting, fogs are among the more prominent of the phenomena attending on the anticyclone ; and storms of wind, rain, and snow are the most prominent features of the weather phenomena attending the cyclone. Diagrams giving these results show that, as regards storms, the number which occur in each month strictly follow the sun, the maximum number being in December and the minimum in June. This is the relation observed for the storms occurring in Scotland taken as a whole.

On the other hand fogs also follow the sun in the number of the monthly occurrences, but in a reverse order, the maximum number occurring in June and the minimum in December. It is to be observed that the maximum period includes the two months June and July, and the minimum the three months November, December, and January.

These elaborate papers on storms and fogs are merely introductory to the wider discussion of weather phenomena which has been undertaken touching the relations of the Ben Nevis observations to storms of winds, widespread clouded skies, severe storms of rain and snow, and fogs to the changing positions day by day of the cyclones and anticyclones of North-western Europe. This research involves an analysis of the daily weather maps for Scotland, showing for each day from July 17, 1890, to this date the geographical distribution of storms of wind, the rainfall, thunderstorm, aurora, and other weather phenomena appended as supplements to the bi-daily weather maps issued by the Meteorological Council. It will be at once evident that this research necessitates heavy labour, stretching over a long period—from two to three years at least.

Mr. Omond's time during the past year has been largely directed to the utilisation of the observations made at the High Level observatories of Europe viewed in connection with the Ben Nevis obrervations and their bearings on weather changes. In connection with this work the observations at the following High Level observatories are being utilised :

In France—Barcelonette, 3,714 feet ; Servance, 3,990 feet ; Gavarnie, 4,452 feet ; Puy-de-Dôme, 4,813 feet ; Aigoual, 5,099 feet ; Mont Ventoux, 6,234 feet ; and Pic de Midi, 9,380 feet. *In Germany*—Brocken, 3,766 feet ; and Schneekoppe, 5,259 feet. *In Austria*—

Semmering, 3,297 feet; Crkvice, 3,599 feet; St. Anton, 4,285 feet; Marienberg, 4,341 feet; Schneeberg, 4,810 feet; Schafberg, 5,827 feet; Rathhausberg, 6,283 feet; Schnittenhoe, 6,349 feet; Obirgipfel, 6,706 feet; and Sonnblick, 10,154 feet. *In Italy*—Monte Cave, 3,166 feet; and Monteversine, 4,518 feet. *In Switzerland*—Chaumont, 3,701 feet; Rigi Kulm, 5,873 feet; Säntis, 8,094 feet; and Great St. Bernard, 8,130 feet. *In Algeria*—Teniet-el-Haal, 3,738 feet; and Aflou, 4,679 feet.

Along with these twenty-seven stations several Low Level stations are utilised in determining the vertical gradients of pressure, temperature, and moisture. Particular attention is given to the different directions of the winds at different heights, differences which so often point clearly to very different distributions of barometric pressure at the higher levels of the atmosphere than what prevails at sea-levels at the same time. It is just these different distributions of pressure in the higher layers of the atmosphere from what prevails at sea-level at the same time which is most likely to aid the forecaster of weather in seeing the most probable distribution of the sea level pressure one day, two days, or even three days in advance.

Now it was pointed out in our report for last year that if the forecaster can guess what the distribution of the barometric pressure will be at some future time, he can state what the weather will be at that time. Hence the whole problem of forecasting resolves itself foreseeing the arrangement of barometric pressure in the future. The distribution of pressure does not shift arbitrarily, but the areas of high and low pressures existing on any one day change into those of the next day by movement over the earth and by increase or diminution in intensity, in accordance with physical laws.

The scientific study of the causes of the movements of these areas of high and low pressures, called respectively anticyclones and cyclones, can only be said to be just beginning; and until this great inquiry has made some substantial progress we cannot have a science of forecasting, as we have now a science of climatological meteorology.

This is the inquiry which Mr. Omond, aided by the staff of the Scottish Meteorological Society, has entered on, and like the inquiry previously referred to will take from two to three years for the preparation of a report showing the general relations of the observations made at the two Ben Nevis Observatories to the coming changes *in the immediate future* in the distribution of the sea-level pressures, which rule the weather one day, two days, or three days in advance.

It is evident that in carrying on this large work Dr. Buchan and Mr. Omond require the help of well qualified assistants, and your Committee have much pleasure in intimating that this has been provided. As intimated in our last report a generous donor in July 1900 sent a handsome donation of 300*l*. to the Directors of the observatories for this purpose, and as the result Mr. Andrew Watt, M.A., has been on the staff during the past year. We have the further pleasure of intimating that another gentleman, who desires to be unknown, has fowarded a cheque for 500*l*. to provide additional help in carrying on these large and expensive inquiries. There is thus every reason to hope that the examination and discussion of the work of the two observatories will be thorough, and will have scientific utility in the general study of the phenomena of weather, and a practical utility in its bearing on weather forecasting.

It was intimated last year that provision had been made for the

maintenance of the observatories to the end of 1901. We have the further pleasure of adding that Mr. Bernard has most generously given a fourth donation of 500*l*., in addition to the 1,500*l*. previously given by him; and the Meteorological Council have agreed to continue their grant of 250*l*. to the Low Level Observatory for another year. Provision is thus made for the maintenance of the two observatories to the close of 1902.

In the meantime the printing of the observations made at the two observatories since 1888 proceeds, and already the first of the three quarto volumes has been printed, and will be issued in the course of next winter. In addition to the observations, this volume will also contain several papers and discussion, many of which have been laid before the British Association in our reports from year to year. The publication of these volumes has been undertaken by the Royal Societies of London and Edinburgh, and the cost is estimated at 1,000*l*.

The Clearing of Turbid Solutions, and the Movement of Small Suspended Particles by the Influence of Light. By Professor G. QUINCKE, of Heidelberg.

[Ordered by the General Committee to be printed *in extenso*.]

BY 'turbid solutions' or 'suspensions' (trübe Lösungen, Trübungen) I mean water in which many small solid or fluid particles are suspended for a long time. The small particles are visible with the microscope. Colloidal solutions with doubtful character will be discussed later.

Sedimentation, or the formation of flocks, flocking, is observed if small quantities of acid or salt solutions are brought into contact or are mixed with the turbid solution.

For instance, the sandbank at the mouth of a river is the effect of the clearing power of the sea water on the particles of clay suspended in the fresh water of the river.

Turbid solutions of clay, kaoline, silica, gum mastic, are flocked by quantities of acid or salt so small that the increase of weight by the clearing substance cannot explain the augmented velocity, or the flocking of the falling particles, or the sedimentation of the turbid solution.

Franz Schulze [1] and Schloesing [2] found $\frac{1}{10000}$ to $\frac{1}{100000}$ of calcium or magnesium salts sufficient to clear suspensions of clay. Bodländer [3] has measured the clearing or coagulating power of different salts for suspensions of kaoline; Hardy [4] for suspension of gum mastic; Spring [5] for suspensions of gum mastic, kaoline, silica. Bodländer found suspensions of kaoline flocked if the quantity of the added salt is greater than a distinct, very small quantity, the 'Schwellenwerth' of the clearing substance. Electrolytes promote, insulators retard, the clearing of the suspensions, (Barus,[6] Bodländer). The clearing power of a salt depends on the valance of the salt and the kation of the electrolyte (Hardy, Spring).

According to Hardy, the particles of gum mastic, or heat-modified

[1] Franz Schulze, *Poggendorff's Annalen*, 1866, vol. cxxix. p. 366.
[2] Ch. Schloesing, *Compt. Rend.*, 1870, vol. lxx. p. 1345.
[3] G. Bodländer, *Gött. Nachr.*, 1893, p. 267.
[4] W. B. Hardy, *Proc. Roy. Soc.*, 1900, vol. lxvi. pp. 111–119.
[5] W. Spring, *Rec. Trav. Chim. des Pays-Bas*, 1900, vol. x. (2 ser. 4), no. 3, pp. 222, 294.
[6] C. Barus, *Phys. Beibl.*, 1888, vol. xii. p. 563.

proteid move in a contrary direction to an electric current. In presence of a minute amount of barium chloride or free acid the particles of gum mastic, or heat-modified proteid, move with the electric current. At the isoelectric point, for a distinct small quantity of barium chloride or acid, the electric movement vanishes and coagulation or precipitation occurs. An explanation of the clearing power of the acids or salts is not given.

In the coagulated solutions I found flocks adhering to the walls of the glass vessels and many air bubbles distributed among the flocks. Both phenomena prove that on the surface of the flocks at least, a short time after formation of the flocks, an oily viscous fluid exists. At the surface of separation of this oily fluid and the surrounding aqueous fluid, a surface tension acts and air bubbles are separated, as at the limit of two heterogeneous fluids. Probably changes of the surface tension of the boundary of oily and aqueous fluid and the periodical spreading of heterogeneous liquid will excite vortices and unite the small suspended particles and form the flocks. The surface forces are the same as the forces which form foam-cells by the contact of alkaline oleates with water, which I demonstrated at the meeting of the British Association at Oxford, 1894. The flocking influence of quantities of clearing matter so very small is now intelligible.

I shall prove that this explanation is the right one.

Alcoholic solution of gum mastic gives in a large mass of water many unseen threads and foam-walls, in which are distributed a great many small visible spheres. If copper sulphate is added to the water with the mastic foam the foam-walls move against the copper sulphate, become clearer, and are dissolved. The spheres and the foam-walls prove the formation of an oily viscous fluid by the action of water and gum mastic, which I will call mastic hydrate, and which possesses a surface tension at the surface of separation from water. The copper sulphate is soluble in water and in mastic hydrate, has the surface tension zero at the boundary with water, and in the boundary with mastic hydrate, and must be spread out on the common surface of mastic hydrate and surrounding water. The spreading excites vortices and draws the surrounding matter towards the spreading centre; the surrounding fluid is stirred up, a new portion of copper sulphate is brought into contact with the mastic surface, spreads out, and so, in short periods, the spreading of the added salt and the formation of vortices are repeated, and the mastic particles are attracted by the copper solution.

The solution of copper sulphate, which is placed by means of a long thin funnel under a turbid solution of mastic in a test tube, will diffuse in the mastic solution, spread out on the surface of the suspended particles, excite vortices, and draw the mastic particles together or against the walls of the test tube, where they will adhere. The connected viscous matter will flow together and form drops, bubbles, or coherent foam-cells, flocks. On the surface of the mastic hydrate, as in all newly formed boundaries of two heterogeneous fluids, the absorbed air is separated in small bubbles. One part of the flocks will rise with the adhering air, the other part with the larger flocks will sink to the surface of the salt solution.

The spreading or vortices of sufficient energy and the connection or flocking of the suspended particles demand a certain concentration of the copper sulphate, corresponding to the 'Schwellenwerth' of Bodländer.

Solutions of NaCl, HCl, $K_2Cr_2O_7$, $FeCl_3$, spread out on the surface of

mastic hydrate, as $CuSO_4$, and have the surface tension zero. The coagulation, or clearing of mastic solution by this salt solution, is explained in the same way as with $CuSO_4$.

Turbid solutions of kaoline in glass cylinders of 100 × 10 cm. form a series of horizontal layers separated by equal intervals. After two months a great many flocks adhere on the shaded side of the glass. Under the microscope the flocks show threads or tubes of a downward flowing liquid, with spheroidal enlargements or contractions (Anschwellungen und Einschnürungen). The sediment at the bottom of the glass cylinder has the appearance of solidified liquid, containing deformed bubbles and coherent foam-cells, smooth spheres of diameter 0·002 to 0·0004 mm., with greater refraction than the surrounding substance.

The particles of kaoline are covered by the action of the water with an oily viscous fluid, probably silica hydrate, on the surface of which another fluid is spread out. The periodical spreading combines the suspended kaoline particles in larger flocks, which slowly sink to the ground or are drawn by the vortices against the glass walls, where the particles covered with oily fluid adhere. The oily silica hydrate forms spheres, bubbles, or coherent foam-cells, and afterwards becomes solidified.

Turbid solutions of $\frac{1}{1000}$ kaoline in test-tube solutions over $CuSO_4$, $FeCl_3$, $CaCl_2$, or $Ca(HO)_2$ give foam-flocks with thin walls in which many little grains are distributed, or with thick foam-walls in which, again, small chambers or cells with thin walls are enclosed. The flocks of kaoline formed in the beginning by the viscous fluid adhere to the glass wall.

Also over solutions of sugar, solutions of kaoline form two thick flock-layers.

Turbid solutions of potash soap have shown flocks over chloroform, sulphide of carbon, aqueous solution of sugar, $CuSO_4$, HCl.

Turbid solution of oleic acid has been flocked by solutions of HCl, $CuSO_4$, chloroform, sulphide of carbon, and sugar; turbid solution of China ink by solution of $CuSO_4$ and HCl.

The order of the flocking solution, determined by the velocity of the clearing, changes with the concentration of the suspended particles.

Electrolytes and insulators may be clearing substances.

The flocks of mastic and kaoline, formed by artificial clearing by means of the light, adhere to the shaded side of the glass-wall.

The views of Barus, Hardy, and Spring on the clearing power of different liquids, especially of the electrolytes, are not confirmed by my experiments. It is not proved that the kation of the clearing electrolyte is the clearing substance.

The flocks of gum mastic in the turbid solution are formed by a thin layer of mastic salt solution (mastixhaltiger Salzlösung), which is connected to the surface of the mastic particles by molecular force. This thin layer of mastic salt solution will develop no sensible electromotive force in contact with the pure salt solution outside, and no movement of the suspended particles with the thin layer by an electric current will be possible. My theory explains the formation of the flocks and of the isoelectric flocks of Hardy, which are not moved by the electric current. The process of clearing is the same in all turbid solutions. All flocked particles, or suspended particles united in flocks, are covered with a thin layer of solution, nearly isoelectric with the surrounding pure salt solution, and *cannot be moved by electric forces.*

If by the influence of light more spreading fluid is formed on the light side than on the shaded side of the suspended particles the suspended particles will go towards the light. I call this phenomenon positive photodromy.

If the influence of light stops the formation of the spreading solution or the spreading film, the flocks would go to the shaded side, or will show negative photodromy.

A retarding influence of the light is not probable, but many physicists suppose with E. Becquerel a retarding or stopping influence of red light in the case of the fluorescence of Sidot-Blende. I think that the negative photodromy may also be explained by the heating effect of the light and the formation of air bubbles on the light side of the suspended particles. The air bubbles will hinder the spreading of the newly formed solution on the surface of the suspended particles, and the vortices of sufficient energy will only exist on the shaded side, and the flocks will go away from the light or show negative photodromy.

Turbid solutions of gum mastic, silica, sodium or potassium silicate, kaoline, gummi gutti, shellac, soap, proteid, can remain apparently unchanged for months or years, but after some weeks or months we can always find flocks at the bottom of the solution. Moreover horizontal layers are formed with more or less suspended particles.

What is the reason of the stability of the turbid solution? Hardy [1] and J. J. Thomson see the reason for the stability in the electromotive force at the boundary of the suspended particles and the surrounding fluid, which hinders the movement of the solid particles, while, according to Dorn,[2] electric work is done by the displacement of the particles. The action is the same as if the viscosity of the fluid had been increased.

That electric work is done by the displacement of suspended particles, or by the displacement of fluids over the solid walls of porous bodies, and that electromotive force exists at this boundary was known before the researches of Dorn, and is a consequence of my old researches on capillary electric currents.[3] If the explanation of Hardy and J. J. Thomson should be right, the turbid solutions must have the greatest stability if the suspended particles show the greatest electromotive force in contact with the surrounding fluid—*i.e.*, sulphur, silica, shellac, suspended in water. But shellac gives turbid solutions of little stability. It may be that the electromotive force at the boundary of liquid and suspended particles may increase the stability of the suspension, but the principal reason of the stability may be that the velocity of the falling particles is not constant, but variable or periodic. The impulses of the periodic velocity are propagated with the velocity of sound, and will be reflected inside or at the bottom of the turbid solution. The direct impulse will interfere with the reflected impulses, and the particles will be collected in horizontal layers at distances of half a wave length.

The air also separated at the common surface of the suspended particles and the surrounding liquid has in many cases an important influence, and will be attached to it or will cover it. The diameter of the air bubbles or thickness of the thin air cover may be so small that it is not possible to see it with the best microscope, but it forms the condensation nuclei for masses of absorbed air previously separated.

[1] Hardy, *Proc. Roy. Soc.*, 1900, vol. lxvi. p. 123.
[2] Dorn, *Wiedemann's Annalen*, 1880, vol. x. p. 70.
[3] G. Quincke, *Poggendorff's Annalen*, 1860, vol. cx. p. 56; 1861, vol. cxiii. p. 546.

In turbid solutions of gum mastic, soap, or oleic acid one may see these air bubbles. In turbid solutions of kaoline or silica they act as a Cartesian diver; the suspended particles and the layers of particles rise if they are lighted up by sunshine and sink again in shadow by a change of density or volume of the air.

Underground Temperature.—Twenty-second Report of the Committee, consisting of Professor J. D. EVERETT *(Chairman and Secretary)*, Lord KELVIN, Sir ARCHIBALD GEIKIE, Mr. JAMES GLAISHER, Professor EDWARD HULL, Dr. C. LE NEVE FOSTER, Professor A. S. HERSCHEL, Professor G. A. LEBOUR, Mr. A. B. WYNNE, Mr. W. GALLOWAY, Mr. JOSEPH DICKINSON, Mr. G. F. DEACON, Mr. E. WETHERED, Mr. A. STRAHAN, Professor MICHIE SMITH, *and* Professor H. L. CALLENDAR, *appointed for the purpose of investigating the Rate of Increase of Underground Temperature downwards in various Localities of Dry Land and Under Water. (Drawn up by* Professor EVERETT, *Secretary.)*

ATTENTION having been called to the copper-mining region on the south coast of Lake Superior as exhibiting an exceedingly slow increase of temperature downwards, the Secretary has availed himself of the kind offices of Professor William Hallock, of Columbia University, to obtain authentic information on the subject. Previous reports contain valuable material furnished by Professor Hallock respecting a deep well at Wheeling, in Virginia.

The region in question is the most northerly portion of the State of Michigan, and includes a tongue of land jutting out some sixty miles into the middle of the lake, terminating in Keweenaw Point, which is marked on all maps. The mine of the Calumet and Hecla Company, which is very extensive, and has upwards of twelve shafts, is nearly in the middle of this tongue; and immediately adjoining it to the west is the Tamarack mine, with five shafts. These two mines are about four miles from the nearest coast (which is the north-west side of the tongue) and about eleven miles from the south-east coast, the tongue being about fifteen miles wide in this part. The ground is high, being 650 feet above the lake, which is itself 600 feet above sea-level. The mineral veins dip to the north-west under the lake, the dip ranging from 22° at the end of the tongue to 56° at its root. The beds consist of a series of compact granular and amygdaloidal traps, sandstones, and conglomerates.

The latitude is 47°, and the mean annual temperature, according to isothermal charts, is 39° or 40° F. The average depth of the lake is about 900 feet, and all the water below the depth of 240 feet was found, by surveys conducted in the months of August and September, to be at about 39° F. As this is the temperature at which water has its maximum density, it probably remains unchanged all the year round. The ground beneath the lake is accordingly at a permanent temperature, practically identical with the mean annual temperature of the air above, and the boundary conditions for regulating underground temperature are practically the same as if all the water of the lake were removed and the air had free access to the bottom. The slope of the bottom in the neighbourhood of the mines in question is about 1 in 54 until a depth of 300 feet has been attained, and becomes gradually less steep to the depth of 700 feet,

which begins at nineteen miles from the shore and continues for fifteen miles further. The slope of the land from the mines down to the shore is about 1 in 40. The contour of the ground and the surface conditions in the neighbourhood may therefore be regarded as normal.

The leading authority on temperature-gradient in this part of the United States is Mr. Alfred C. Lane, the Michigan State Geologist. He writes in 'Mineral Industry' (vol. iv. 1895, p. 767) :—

'It is certain that, in the Lake Superior region, the rate of increase of rock temperature is not far from 1° in 100 feet from a surface temperature near 40°. For example, at 4,450 feet, the bottom of the North Tamerack shaft, the rock is at 84° F.'

Alluding to the preliminary announcement by Professor Alexander Agassiz, president of the Calumet and Hecla Mining Company, of the temperatures 59° F. at 105 feet, 79° F. at 4,580 feet, he says :—

'Since at 105 feet the rock temperature should be near the mean annual temperature of the locality, and since the mean annual temperature of Calumet is, according to all isothermal maps, near 39°, and a mean annual temperature of 59° is found somewhere near Tennessee, I do not think we can safely assume a gradient very much less than 1° in 100 feet after all.'

President Agassiz's announcement appeared in the 'American Journal of Science' for December 1895, p. 503, in the form of a preliminary communication to the editors, with the statement :—

'We propose when we reach our final depth, 4,900 feet, to take an additional rock temperature, and then publish the full details of our observations.'

This depth was reached not long afterwards, the fact being recorded in the 'Mining Journal' for September 1896; but the promised details have never been given to the public; and a letter addressed by the Secretary to Professor Agassiz in 1896 elicited the information that the rate of increase had turned out to be different from what it was believed to be when the preliminary announcement was made.

The evidence tendered in favour of the abnormally slow increase of 20° F. in 4,475 feet, or 1° in 224 feet, has thus been practically withdrawn. Professor Hallock, writing in January last, says :—

'The observation of temperature in the Calumet and Hecla mine, to which you refer, is thoroughly discredited in this country.'

With the view of probing the matter to the bottom, Professor Hallock (on the suggestion of the Secretary) made arrangements for personally exploring, in the spring and early summer, the temperature conditions of the mines; but in June he wrote :—

'The Mining Company [the Tamarack Company], after having promised me permission to make temperature observations, withdrew the permission, and declined to permit me to enter the shaft.'

The proposed trip was accordingly abandoned. Professor Hallock has, however, sent large-scale maps and sections, and Mr. Lane has, at his request, furnished information respecting underground temperature in

various parts of Michigan. It includes temperatures of deep wells spouting above ground and of shallow springs. Mr. Lane's general result is that—

'in the flat, undisturbed sedimentaries of the Lower Peninsula [between Lake Michigan and the lower lakes] the geothermal gradient is not far from 1° in 67 feet; while in the Upper Peninsula, near Lake Superior, the gradient is perhaps a little lower than 1° in 100 feet. This difference may be ascribed to the difference in conductivity, to which the geothermal gradient should be inversely proportional. The Upper Peninsula rocks are probably more conductive (trap ·007) when dry, and certainly are less porous and contain less water than those of the Lower Peninsula (limestone ·005, sandstone ·002. There has been no volcanic or very extensive orogenic disturbance since early Cambrian times, and but little Palæozoic faulting and folding. You will notice that the temperatures of shallow flows are higher than the mean annual temperatures as derived from the Weather Service; which is not surprising when we consider that in the winter the surface of the ground is often blanketed with snow and not freezing, when the air temperatures are very low.'

Mr. Lane estimates the 'mean annual temperature' for the Calumet district at 38°·6, and the 'mean temperature at the depth of no variation' at 40°. If we take this latter as the temperature at 50 feet, and compare it with the temperature 84° at 4,450 feet in the Tamarack mine, we have an increase of 44° F. in 4,400 feet, or 1° in 100 feet. Mr. Lane's estimate for the Calumet district is 1° F. in 107 feet. He states that numerous corroborative data indicate a gradient lying between 1° in 100 feet and 1° in 115 feet.

No authorities are cited for the conductivities which Mr. Lane assigns to the rocks, and fuller information on this point is desirable; but, in view of the fact that the President of Section C last year characterised the variation in the British Isles 'from 1° in 34 feet to 1° in 92 feet' as 'a surprising divergence of extremes from the mean,' it is well to emphasise the connection between gradient and conductivity. If there is anything like uniformity in the annual escape of heat from the earth at different places, there must necessarily be large differences in geothermic gradients, since the rate of escape is jointly proportional to the gradient and the conductivity.

The investigation of underground temperature is being energetically taken up by the United States Geological Survey. Mr. N. H. Darton has for some years been engaged in collecting data with a view to the preparation of an isogeothermal map of the United States.

Brief allusions have appeared to observations taken in 1893 in a bore at Paruschowitz, near Rybnik, in Upper Silesia, reputed to be the deepest in the world. The details, strange to say, have never yet been published, but they have been kindly furnished for the purposes of this report by the Prussian mining authorities.

The bore is one out of a large number (400 or more) which have been sunk by the Prussian Government for the purpose of exploring the mineral resources of the country. A full account of the mode of sinking it and the difficulties which were encountered was given by Bergrath Köbrich at the ninth 'Wanderversammlung' of boring engineers, and is printed in the mining journal 'Glückauf' for 1895, pp. 1273–1277.

The boring was begun in January 1892, and finally discontinued in

August 1893. In May 1893 the operations were suspended for the purpose of making changes in the machinery; and it was during this interruption, which lasted three months, that the observations were taken. The bore had attained a depth of 2,002 metres, exceeding by 255 metres that of the Schladebach bore, which was previously the deepest in the world. When boring was resumed after the interruption, and had added about a metre to the depth above mentioned, the boring tool broke, owing to caving in, which proved to be of so serious a character as to render further progress hopeless. The total depth attained is given as 2,003·34 metres.

The first 200 metres bored through consisted mainly of a greenish grey clay or marl (Tegel), which was liable to swell and crumble after a time if exposed to water. It also held the tubing with a grip which was inconveniently tight. At about 250 metres a seam of coal was passed through; and in all eighty-three coal seams were found, with a total thickness of about 90 metres. No mention is made of any springs being tapped, but 14 metres of quicksand were passed through at the depth of 200 metres, immediately above the Coal-measures. The seams of coal alternated with beds of sandstone and shale.

The lower half of the bore, from 1,014 metres downwards, was not tubed, but the upper half contained eight different sizes of tubing. The first and largest extended from the top to 70 metres. Inside of this was the second, reaching from the top to 107 metres. Within this was the third, reaching from the top to 189 metres, and it was during the sinking of the third that the diamond borer was substituted for the percussive drill. The fourth size extended from the top to 260 metres; the fifth from the top to 319 metres; the sixth from the top to 571 metres; the seventh from the top to 1,014 metres; and the eighth from 540 metres to 1,014 metres, the necessity for this eighth tube having arisen from accidental injury to the seventh. An accident which subsequently occurred broke away a large portion of the eighth tube also, and as repair was found to be impossible, a considerable length of the bore (from the depth 571 metres to the depth 754 metres) was left without tubing, constituting a standing source of danger and trouble.

In place of the solid rods employed for supporting and working the old percussive drills, hollow rods are employed in diamond boring, and water forced down the interior of the hollow rods washes up the *débris* through the surrounding space. The hollow rods are usually of wrought iron, and this was the case at Paruschowitz till the depth of 1,450 metres was reached, when, in order to diminish the enormous weight, it was decided to replace the wrought iron by Mannesmann steel tubes; a change which was attended with great advantage during the remainder of the boring.

As regards the diameter of the bore, the tubing which lined the first 450 metres had an internal diameter of 92 millimetres. From this depth to 571 metres the diameter was 72 millimetres. Then occurred an untubed interval of 183 metres of considerably larger diameter, the tubing of 72 millimetres diameter commencing again at 754 metres, and continuing to 1,014 metres, from which depth to the bottom at 2,002 metres there was an untubed portion of uniform diameter which had been bored with a diamond crown [illegible] millimetres.

The method of plugging to prevent convection currents, which was employed at Sperenberg and Schladebach, was not repeated at

Paruschowitz, possibly on account of the danger of caving in; but in order to fulfil the same purpose as completely as the circumstances permitted, mud was pumped into the bore, and left undisturbed for some time, that it might acquire the permanent temperature of the strata. When observations were commenced, the last 40 metres of mud were found to have become so consolidated that the hollow rod employed for lowering the thermometers could not be forced into it, and the lowest observation that could be obtained was at 1,959 metres, about 200 metres deeper than the deepest obtained at Schladebach. The following is the record of the observations:—

Reference Number.	Depth, Metres.	Temp. Cent.	Reference Number.	Depth, Metres.	Temp. Cent.
		°			°
1	6	12·1	33	998	39·3
2	37	13·1	34	1,029	40·0
3	68	14·3	35	1,060	41·4
4	99	14·6	36	1,091	42·4
5	130	15·6	37	1.122	43·4
6	161	16·0	38	1,153	45 1
7	192	16·5	39	1,184	46·0
8	223	17·3	40	1,215	46·4
9	254	18·1	41	1,246	47·0
10	285	18·9	42	1,277	48·4
11	316	20·1	43	1,308	48·5
12	347	20·4	44	1,339	49·0
13	378	21·1	45	1,370	49·6
14	409	21·8	46	1,401	50·0
15	440	22·5	47	1,432	50 1
16	471	23·5	48	1,463	52·8
17	502	24·6	49	1,494	53·4
18	533	25·4	50	1,525	53·8
19	564	26·8	51	1,556	55·0
20	595	28·8	52	1,587	55·8
21	626	29·1	53	1,618	56·2
22	657	30·4	54	1,649	58·6
23	688	30·8	55	1,680	60·3
24	719	31·3	56	1,711	61·4
25	750	31·5	57	1,742	62·1
26	781	31·6	58	1,773	63·6
27	812	32·8	59	1,804	64·8
28	843	34·1	60	1,835	65·5
29	874	35·4	61	1,866	65·5
30	905	35·8	62	1,897	66·9
31	936	37·0	63	1,928	67·5
32	967	37·3	64	1,959	69·3

Each temperature recorded in the list is the mean of the indications of six thermometers, which were enclosed together in a steel case, supported inside the hollow rod near its lower end. The case had been tested and found watertight under a pressure of 250 atmospheres. The thermometers were similar to those described in our account of the Schladebach observations—mercury thermometers of the 'overflow' kind, open at the top, their indications being interpreted by placing them in water which is gradually warmed up till the mercury is on the point of overflowing.

As the operation of lowering a thermometer to any point in a bore

and hauling it up again disturbs the contents of the bore at all parts above this point, the general rule is to take the shallowest observation first and work downwards. On the other hand, when there is danger of caving in, it may be desirable to begin by securing the most valuable observation—that is, the deepest—and to work upwards. This latter was the order of observation adopted at Paruschowitz, the points of observation being at the uniform distance of 31 metres, the lowest at 1,959 metres, and the highest at 6 metres. This makes sixty-four determinations, each being the mean of six readings.

Though the observations were taken under less favourable conditions than those at Schladebach, they are of very unusual interest, and the withholding of them from publication till the present time is a notable instance of excessive modesty. When they are plotted the curve obtained exhibits a satisfactory amount of regularity, and does not depart very far from a straight line joining its two ends. Of the two most conspicuous irregularities one extends over the portion where 183 metres of tubing were broken away the temperature here being a degree or two higher than one would have expected—and the other at the point where the change was made from wrought-iron rods to Mannesmann steel, the interval between the two consecutive temperatures on opposite sides of this point being about three times the average interval. Several other points can be selected which show an excess or defect of temperature amounting to 1°, but this is only what was to be expected from the alternations of different rocks. In some condensed reports of Bergrath Köbrich's communication (but not in the full paper as given in 'Glückauf') the irregularities are attributed to chemical action in the coal seams, causing in some cases a heating and in others a cooling; but in the absence of more direct evidence this explanation seems rather forced.

The curve for the shallower portion from 6 metres to 533 metres is approximately a straight line of gradient 1° C. in 39·6 metres; while the curve for the deepest portion—1,680 metres to 1,959 metres—shows an average gradient of 1° C. in 31·0 metres. The intermediate portion—533 metres to 1,680 metres (which is rather more wavy)—has an average gradient of 1° C. in 32·9 metres.

Comparing the shallowest observation, 12°·1 at 6 metres, with the deepest, 69°·3 at 1,959 metres, we have an increase of 57°·2 in 1,953 metres, which is at the rate of 1° C. in 34·1 metres, or 1° F. in 62·2 feet. This general average is the only result that has hitherto been published.

No doubt seems possible as to the correctness of the determination 69°·3 at 1,959 metres. The firmness of the clay, being sufficient to prevent a hollow rod weighing several tons from going deeper, must have been sufficient to prevent convection.

As regards the determination 12°·1 C. at 6 metres, one naturally compares it with the temperature found at precisely the same depth in the Schladebach bore, which was 8°·3 R., or 10°·4 C. Paruschowitz is a degree or degree and a half further south than Schladebach, but is 152 metres higher, which about compensates the difference of latitude, so that one would expect their temperatures to be the same. Further light is thrown upon the question of the temperature of Paruschowitz by comparison with the known temperatures of places lying around it.

The following particulars respecting neighbouring places and their mean annual temperatures are taken from Hann's 'Klimatologie' (Stutgart, 1897), vol. iii. p. 147:—

—	Lat. N.		Long. E.		Height	Temp. C.
	°	′	°	′	M.	
Ratibor	50	6	18	13	198	8·1
Cracow	50	4	19	59	220	7·8
Prague	50	5	14	26	202	8·8
Eger	50	5	12	22	455	7·1
Datschitz	49	6	15	26	465	6·4
Brünn	49	12	16	37	210	8·4
Oppeln	50	40	17	55	175	8·2
Eichberg	50	55	15	48	349	6·8
Breslau	51	7	17	2	147	8·3
Görlitz	51	10	15	0	210	8·0
	To compare with					
Paruschowitz . . .	50	7	17	33	254	—

the latitude and longitude of Paruschowitz (in absence of more exact information) being identified with those of the nearest town, Rybnik.

The nearest of these places is Ratibor, which is only twenty English miles distant, and has the same latitude. Its temperature is 8·1, and Paruschowitz, being 54 metres higher, should have a temperature of about 7·8. The mean of the temperatures of the ten places is also 7·8, their mean latitude being 50° 31′ and mean height 235 metres. It appears certain that the temperature of Paruschowitz cannot differ by more than a few tenths of a degree from 8·0; and it is not usual for the mean annual temperature at the depth of 6 metres in the soil to differ by more than a few tenths from the mean temperature of the air. The observed temperature 12·1 at 6 metres appears then to be about 4° too high.

This was apparently the latest of the sixty-four observations; and the sixty-three lowerings and raisings again of the thermometers with their supporting rods through the mud which filled the bore would carry down colder mud from the top and replace it by warmer mud brought up from below.

Another cause tending to make the temperature at 6 metres too high is suggested by comparing the temperature 10°·4 observed at this depth at Schladebach with 8°·4, which is given by Hann[1] as the mean temperature of Leipzig, the nearest large town. The isolation by plugging in the Schladebach bore was very effective while it lasted; but it probably did not last long enough to restore the normal temperatures of the layers of rock surrounding the upper portion of the bore, after their prolonged exposure to warm water brought up from below during the progress of the boring.

The highest temperature that seems at all possible for the depth of 6 metres at Paruschowitz is 9° C. If we adopt 8·3, which is more probable, we have an increase of exactly 61° C. in 1,953 metres, or 1° C. in 32 metres, or 1° F. in 58·3 feet.

Treating the Schladebach observations in the same way, if we adopt 8·6 as the temperature at 6 metres, we have an increase of 48° C. in 1,710 metres, or 1° C. in 35·6 metres, or 1° F. in 65 feet. This exactly agrees with Herr Dunker's deduction as given in our report for 1889.

It is very desirable that direct observations of the mean annual temperature of the soil at a small depth (say 1 metre or 2 metres) should be

[1] *Loc. cit.*

taken at both Schladebach and Paruschowitz for the purpose of removing all doubt.

Since the presentation of their last report in 1895 the Committee have to deplore the loss of two valuable members, Professor Prestwich, who compiled the most complete account of underground temperature observations yet published, and Mr. G. J. Symons, who, ever since the formation of the Committee in 1867, has been one of its most active members.

They have pleasure in announcing that Mr. Bennett H. Brough, Secretary of the Iron and Steel Institute, who has rendered large assistance in obtaining the material for the present report, has consented to serve on the Committee.

Note sur l'Unité de Pression. *Par le* Dr. C. E. Guillaume.

[Ordered by the General Committee to be printed *in extenso.*]

L'utilité de l'emploi d'une unité de pression dérivée du système C.G.S. n'est pas contestable. De plus, une expérience déjà longue et souvent répétée nous a enseigné qu'une unité n'est vraiment admise en pratique que lorsque sa valeur normale en fonction d'un étalon a été fixée, de manière à ce que la réalisation précise de cette unité ainsi que sa représentation matérielle soit parfaitement assurée. L'adoption d'une valeur normale de l'unité de pression, ou, si l'on veut, d'un étalon de pression dérivé du système C.G.S., constituerait donc une utile addition au système généralement employé dans toutes les branches de la science.

Les seules questions se rapportant à l'unité de pression au sujet desquelles il soit nécessaire de discuter encore avant l'adoption définitive d'un étalon sont les suivantes :—

Quel sera le multiple de l'unité C.G.S. qui sera considéré comme unité de pression pour la pratique ?

Quelle sera sa représentation ? Eventuellement sera-t-il avantageux de se rallier à un étalon définissable par un nombre simple, et quel sera ce nombre ?

Quels sont les domaines auxquels l'unité de pression devra être appliquée ? En particulier conviendra-t-il d'abandonner la pression normale définie par Laplace, et adoptée par les météorologistes et les physiciens ?

Multiple.—Le choix du multiple est indiqué par l'utilité qu'il peut y avoir à se rapprocher, pour la nouvelle unité, des grandeurs des unités les plus usuelles. Ces dernières sont l'atmosphère et le kilogramme par centimètre carré, qui enserrent, à moins de 2 pour 100 près, et par un heureux hasard le produit par 10^6 de l'unité C.G.S.

On pourrait faire à ce multiple une seule objection, c'est de se trouver en dehors du système cohérent auquel le *watt* et le *joule* ont été rattachés, de telle sorte que le produit de la nouvelle unité de pression par le centimètre cube serait égale au dixième de l'unité pratique d'énergie, et non à l'unité pratique elle-même. Cependant il ne semble pas que ce défaut soit assez grave pour faire renoncer à l'avantage de se trouver si près des deux principales unités usuelles que, pour beaucoup d'applications, le changement serait insensible.

Représentation et Valeur.—L'étalon de pression serait convenablement représenté par une colonne de mercure, ainsi qu'il a été fait jusqu'ici pour

la plupart des unités de pression employées. L'atmosphère métrique et l'atmosphère britannique sont dans ce cas, et ne diffèrent que par la température à laquelle le mercure est considéré, la hauteur de la colonne et le lieu de son exposition à l'attraction de la terre. En physique les pressions qui ne sont pas exprimées dans le système C.G.S. sont rapportées à l'atmosphère, et par là même à une colonne de mercure, ou sont directement exprimées en fonction du millimètre de mercure. L'adoption générale de la réduction à 0°, même par les météorologistes qui, suivant le système britannique, ramènent la longueur mesurée sur l'échelle en pouces à 62° F., ne laisse aucun doute sur la température de la colonne mercurielle, qui devra être celle de la glace fondante.

Le dernier élément qui reste à fixer, en dehors de la hauteur elle-même de la colonne mercurielle, qui sera donnée par le calcul, est la valeur de l'accélération de la pesanteur, à laquelle la pression sera due. Aussi longtemps que les géodésiens ont pu croire à l'existence d'une valeur normale de l'accélération, définissable par une latitude et une altitude, par exemple par la latitude de 45° et le niveau de la mer, il ne semblait pas possible d'admettre une autre valeur de l'accélération que cette dernière. Mais les recherches de ces dernières années ont fait découvrir les anomalies locales qui rendent un peu incertaine et variable la valeur de l'accélération que l'on avait considérée comme normale.

La valeur de l'accélération donnée par la réduction des stations du littoral méditerranéen est de 980,714, en léger excès sur la valeur de Greenwich et sur la plupart des stations continentales ; ce n'est pas cependant une valeur exceptionnelle, et la réduction de certaines stations donne des nombres encore sensiblement plus élevés.

La masse spécifique du mercure, c'est-à-dire le quotient de la masse d'une certaine quantité de mercure par son volume à 0°, est, dans le système C.G.S., égale à 13,5950 à 3 ou 4 unités près du quatrième chiffre décimal. En combinant les deux nombres qui précèdent, on trouve, pour la pression exercée par une colonne de mercure de 1 mètre, à 0°, et dans les conditions susdites de la pesanteur :

1,33328 *mégadyne par centimètre carré.*

La pression qui devrait être adoptée comme unité pratique serait donc représentée par une colonne de mercure de 75,003 cm. à 0° et dans les conditions indiquées ci-dessus.

Les incertitudes de ce nombre portent encore :

1° Sur la masse du décimètre cube d'eau ;
2° Sur la densité relative du mercure et de l'eau ;
3° Sur la valeur normale de la pesanteur.

Les deux premières sont encore de l'ordre de deux unités du troisième chiffre décimal, et diminueront avec le temps ; la troisième fait intervenir un doute plus grand, si l'on considère l'ensemble du Globe, et ce doute ne fera probablement que s'accentuer à mesure que les anomalies seront mieux étudiées.

On peut conclure de ce qui précède que l'unité pratique de pression pourrait être représentée par une colonne de mercure de 75,000 cm. de hauteur à 0° sans que l'on sorte des incertitudes résultant encore des mesures, et surtout de celles qui sont inhérentes au problème lui-même et à la constitution de notre globe.

On pourrait, pour diminuer cette incertitude, renverser le problème,

et, après avoir serré de plus près la valeur de la masse spécifique du mercure, adopter une valeur normale de l'accélération de la pesanteur *telle que l'unité de pression soit représentée rigoureusement par une colonne mercurielle de* 75 *cm. de hauteur.* Cette adoption n'aurait rien d'absurde puisque les géodésiens sont dès maintenant impuissants à définir une intensité normale de la pesanteur sans s'engager dans une voie arbitraire, et puisque, par surcroît, la valeur résultant de la définition ci-dessus serait comprise entre les valeurs parmi lesquelles les géodésiens pourraient choisir.

Mais on peut se demander si une telle définition est devenue nécessaire pour les besoins de l'unité de pression. Il faut distinguer, en effet, deux cas de l'emploi de cette unité. Toutes les fois qu'une précision de l'ordre de 1/25 000 ne devra pas être dépassée, c'est-à-dire dans l'immense majorité des applications, la différence entre la valeur actuellement *la plus probable* de l'unité de pression et la valeur ronde fournie par une colonne de mercure de 75 cm. est entièrement négligeable. Dans les cas, en petit nombre, où une haute précision est exigée, les réductions à des conditions normales ne pourront pas être faites sans que l'on connaisse, au lieu même de l'observation, la valeur de l'accélération ; celle-ci devra, dans ce cas, être déterminée par des expériences directes et très précises.

Le problème actuel est très analogue à tous ceux, en nombre bien plus grand, dans lesquels intervient la masse spécifique des corps, déduite de leur densité, et de la masse spécifique de l'eau. Dans toutes les applications ordinaires, cette dernière est admise comme étant égale à l'unité, tandis que, dans les calculs très précis, il est nécessaire, en principe, de tenir compte de la très petite erreur commise dans la construction du kilogramme.

Extension.—Il reste à fixer les domaines dans lesquels il sera utile d'employer l'unité rationnelle de pression, et c'est là un point assez délicat. On peut s'attendre, d'ailleurs, à ce que cette unité n'arrive pas, dès le début, à toute l'extension dont elle est susceptible, et qu'elle ne gagne que de proche en proche les domaines auxquels elle devra s'appliquer ; c'est pourquoi, tout en recommandant son adoption aussi universelle que possible, il faudra s'attendre à ne la voir pénétrer que peu à peu dans l'usage.

Les cas bien indiqués de son application sont tous ceux où n'interviennent que des considérations d'élasticité, dans les solides, les liquides et les gaz. Par une extension naturelle on y comprendra les phénomènes osmotiques, et ceux qui en dérivent. Mais on peut se demander légitimement s'il serait praticable d'adopter l'unité rationnelle comme pression normale en météorologie, et dans la détermination de la température normale d'ébullition de l'eau pour la fixation du point supérieur de l'échelle thermométrique.

Sur ce point les avis peuvent être très partagés. D'une part on peut craindre à juste titre le changement dans toutes les constantes thermiques que l'adoption de la nouvelle unité, comme pression normale, entraînerait avec elle. D'autre part, on peut se demander s'il existe un lien logique entre les deux unités.

Le voisinage de l'atmosphère normale et de l'unité pratique C.G.S. aurait rendu, il y a un certain nombre d'années, le changement facile, et même on peut dire que, si le système C.G.S. avait été développé dès les débuts de l'extension du système métrique, la mégadyne par centimètre carré aurait eu bien des chances d'être adoptée comme pression normale. Mais la définition du point 100 des thermomètres repose sur

des considérations pratiques, et sur une convention tout à fait arbitraire. Si la nouvelle unité de pression était très éloignée de l'atmosphère, la question ne se poserait même pas, et on considérerait comme absurde de définir comme température normale d'ébullition de l'eau celle qui correspond, par exemple, à une demi-atmosphère ou à deux atmosphères.

Donc, bien que par des raisons de simple unification, ou des raisons d'élégance scientifique, on ne puisse nier qu'il doive être plus satisfaisant de ne posséder qu'une seule unité de pression, il ne faut pas perdre de vue le fait que, aussi longtemps qu'il s'agit simplement de la thermométrie, et des mesures qui en dérivent immédiatement, il n'y a aucune raison logique qui oblige à partir d'une unité de pression reliée au système C.G.S. et aucune nécessité à rattacher le point de départ de la thermométrie à des considérations dépendant de l'élasticité.

On peut, cependant, envisager le problème par un autre côté particulier, qui militerait en faveur d'une seule unité pour les deux domaines. Nous admettons comme évident que les constantes élastiques des liquides et des gaz doivent être exprimées en fonction de l'unité rationnelle de pression. Les diverses constantes définissant l'état d'un liquide et de sa vapeur en fonction de la température et de la pression devront donc dépendre de l'unité employée pour mesurer cette dernière. Ainsi, la température normale d'ébullition devra logiquement être donnée sous la pression que nous considérons comme normale ; et, si nous rapportons les températures à celles que l'on obtient en désignant par 100 celle qui résulte de l'ébullition de l'eau sous cette même pression, la loi des états correspondants se présente sous une forme numériquement simple, tandis que, en conservant la définition ordinaire du point 100 de la thermométrie, cette loi se présente sous une forme compliquée.

Il resterait seulement à examiner si la simplification résultant de l'adoption de la même unité dans les deux cas, adoption qui certainement serait logique, compense la perturbation qui résulterait d'un changement de toutes les données thermiques accumulées depuis un siècle.

Il n'est pas inutile de rappeler en effet que le changement de 76 à 75 cm. de mercure modifierait l'intervalle fondamental de 0,4 degré environ, et les températures météorologiques ordinaires d'une quantité de l'ordre du dixième de degré. Il est vrai que ce changement serait peu sensible, puisque la réduction au thermomètre à hydrogène, encore très incomplètement faite en météorologie, entraîne déjà une modification du même ordre. D'autre part les données relatives à la dilatation, aux chaleurs spécifiques, aux chaleurs de combustion et de combinaison, les points de fusion, etc., seraient déplacés ou modifiés de 4/1000 environ. Seules, les températures d'ébullition seraient modifiées dans une moindre proportion, puisque la nouvelle pression leur serait appliquée.

La question est, comme on le voit, extrêmement complexe. Elle peut se résumer en ces termes :

Il est utile et même urgent d'adopter une unité de pression basée sur le système C.G.S. Cette unité doit être égale à 1 million de fois l'unité fondamentale. Pour tous les besoins de la pratique courante, et même des mesures scientifiques, à l'exception des mesures de haute précision, cette unité peut être représentée par une colonne de mercure de 75 cm. de hauteur à 0° et dans les conditions de la pesanteur encore envisagées comme normales par les physiciens. Pour les mesures très précises, il est nécessaire de connaître l'intensité de la pesanteur au lieu de l'observation, afin de pouvoir exprimer réellement la pression en unités C.G.S.

La nouvelle unité doit s'appliquer à tous les cas de l'élasticité. Il convient de ne prendre aucune décision pour la thermométrie avant d'avoir approfondi d'une part les simplifications qui résulteraient pour la physique des fluides et notamment la loi des états correspondants de l'emploi d'une seule unité, et, d'autre part, la perturbation qu'introduirait dans la thermométrie et les sciences dérivées un changement dés bases de l'échelle des températures.

Alloys.—Report of the Committee, consisting of Mr. F. H. NEVILLE *(Chairman and Secretary),* Mr. C. T. HEYCOCK, *and* Mr. E. H. GRIFFITHS, *appointed to investigate the Nature of Alloys.*

THE Committee on alloys beg leave to report that Messrs. Heycock and Neville have been continuing their study of the copper-tin alloys.

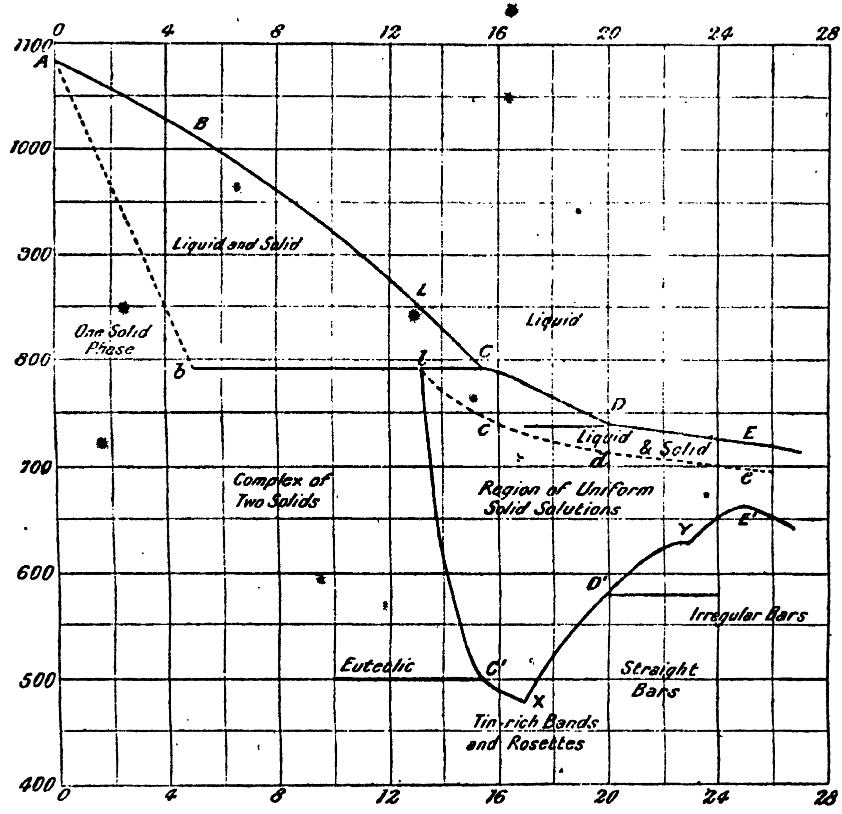
A preliminary statement of the results obtained has been published in the 'Proceedings of the Royal Society,' vol. lxviii. 1901, pp. 171–178. A fuller account will be presented to the Royal Society shortly ; in the meantime the following summarises their conclusions.

The work has been directed towards a verification of Roozeboom's theory of solid solutions in its application to the copper-tin alloys. Pyrometric observations have shown that when one of these alloys cools from a high temperature at which it is completely liquid there is often an evolution of heat, not only at the freezing point, but also at one or more temperatures far below that of solidification. This is well seen in the cooling curves published by Sir William Roberts-Austen and Dr. Stansfield some years ago in their reports on alloys. We have found it convenient to repeat some of these cooling curves, which show very well the remarkable nature of these lower halts and the large amount of heat evolved at them. Roberts-Austen and Stansfield have shown in their fourth report on alloys, and more recently in their paper on alloys published in the 'Proceedings of the Congrès International de Physique,' that if a continuous line in the concentration temperature diagram be drawn through these lower halts a curve is obtained very similar to a freezing-point curve. We have reproduced this curve so far as our cooling curves enable us to do so, and in the figure the line C'XD'YE' is a copy of this curve. Our cooling curves and the C'E' curve have a certain value as confirming the original ones of Roberts-Austen and Stansfield, but we are not prepared to say that they contain anything new ; in fact our C'E' curve is incomplete. We traced these curves because they were needed for our later work.

In our figure the upper curve ABCDE is the freezing-point curve—the 'liquidus' curve, as Roozeboom calls it. The dotted line *Ablcde* is a rough drawing of the 'solidus' curve of Roozeboom so far as our experiments determine it. This curve is defined by the statement that when the temperature of an alloy falls below the 'solidus' it sets to a solid mass ; the 'solidus' might in fact be called the *melting point* curve. The dotted line *l*C' is a continuation of Roberts-Austen and Stansfield's curve. The numbers at the base of the figure give the atomic percentages of tin contained in the alloys, so that DD' on the 20 line corresponds to Cu_4Sn, and EE' to Cu_3Sn. As will be seen, the figure does not deal with alloys much richer in tin than the latter formula.

As a microscopic study of the alloys, made in conjunction with a study of the freezing-point curve, has proved that in many cases the structure of the alloys could not possibly have arisen *during* solidification, but

must have had its origin at lower temperatures, we have attempted to obtain a permanent record of the structure of the alloys at different stages of temperature by cooling them slowly from a molten state to selected temperatures, and then chilling them. When an alloy had solidified before the moment of chilling, the subsequent changes in structure are generally very minute, often sub-microscopic, even if they take place at all. It may be doubted whether the chilling does absolutely prevent the later changes, but it enables us to distinguish the large scale structures already existing before the chill from the necessarily much more minute



structure formed during and after the chilling. We are thus by chilling, polishing, and etching able to form very trustworthy conclusions as to the structure of an alloy immediately before it was chilled.

Numerous experiments of this kind show that an alloy chilled in the region of temperature between the solidus and liquidus contains large primary combs which, from their size, must have been formed before the chilling; and that between them one often sees a crop of minute primaries similar to the large ones, but formed during the chilling. When the polished surface of a section of alloy is heated in the air the combs oxidise more rapidly than the mother substance in which they are imbedded. They are also softer than the ground, for by prolonged polishing they are eaten out into a pattern. These peculiarities, as well

as the behaviour of the alloys to etching reagents, make it certain that the combs are richer in copper than the average of each alloy or than the mother substance round them. The alloys chilled between the liquidus and the solidus were partially liquid at the moment of chilling, and as the chill was effected by dropping the alloy into water, the result was often to granulate the alloy; one always finds in these chills more or less of a tin-rich mother substance. Alloys which had been cooled below the solidus before chilling are never granulated, and never show the second crop of primaries; they must have been solid before the chill. Moreover, in the case of the AB alloys, when chilled below the solidus, the primaries fill the alloy; a sure proof, as it seems to us, that an alloy becomes solid when its temperature falls below the solidus. This is still more marked in the case of the LCDE alloys, for if these are chilled below the solidus, but above Roberts-Austen and Stansfield's curve, they appear to be homogeneous, though sometimes lines can be seen dividing the area of the etched surfaces into irregular polygons. Below the solidus the primaries are lost, not because they cease to exist, but because they have completely filled the alloy and assimilated the mother substance in which they grew. It appears, therefore, that each of these alloys is an approximately uniform mixed crystal phase when its temperature lies between the solidus and Roberts-Austen and Stansfield's curve. On the other hand, alloys whose percentages lie between B and L do not solidify homogeneously. If chilled below the *blC* line they are solid, but they contain copper-rich primary combs imbedded in tin-rich mother substance; near B the combs preponderate, but with more tin the mother substance grows until at the percentage of L it forms the bulk, and in certain chills the whole of the alloy. Moreover, if chilled above C′ the mother substance appears uniform, while below C′ it breaks up into a minute eutectic of two bodies. Successive chills of one of these alloys at a series of temperatures from *blC* to C′ show a remarkable growth of the primaries. For example, in the chills of Sn_{12} taken close to *blC* the combs of copper-rich primary are scanty and the lobes are rounded, but as the chilling temperature is lowered the combs grow and become more angular and fantastic. Alloys between L and C show copper-rich primaries if chilled above *lc*, but these vanish in the chills between *lc* and *l*C′, while when the temperature falls below the curve *l*C′ a new copper-rich crystallisation appears. Photographs of the alloy $Cu_{86 \cdot 5}Sn_{13 \cdot 5}$ are enclosed which illustrate these features.

In the same way, the CD alloys which show copper-rich primaries if chilled above *cd*, and are uniform solid solutions between *cd* and C′D′, are found to contain a tin-rich crystallisation of bands and rosettes if chilled below the latter curve. The photographs 4, 5, and 6 of the paper published in the 'Royal Society Proceedings,' plate 3, vol. lxviii., reproduce these facts. The alloys of the branch DE, and beyond, present very similar phenomena. They solidify in the narrow range of temperature between DE and *de*, but the solid solutions of the region below *de* are very unstable, and the habit of crystallisation of the solid phase that separates out along D′E′ differs from that of the branch XD′, a minor change showing itself near Y.

Thus we see that Roberts-Austen and Stansfield's curve, in its relation to the physical or chemical changes it indicates, closely resembles a freezing-point curve, except that above it there is an unsaturated solid solution, instead of the region of unsaturated liquids that lies above a freezing-point curve. The points on the curve correspond to saturated solids, while

below the curve the saturation has broken down, and the solid solution has separated into two solid phases. Just as would be the case with a freezing-point curve, the phase which first crystallises on the descending branch lC' is copper-rich, while that of the ascending branch X E′ is tin-rich. Moreover, when the temperature falls to the eutectic angle C′ or X, the residual matter breaks up into the solid eutectic, apparently common to all the alloys from B to D.

The solid at D′ is practically homogeneous even after the transformation of the lower curve has taken place; that is, the slowly cooled alloy here contains one phase: this may be the compound Cu_4Sn. The slow cooled alloy at E is also homogeneous, although when barely solid it is far from being so. There can be hardly any doubt that this alloy when slowly cooled or chilled below E′ is the pure compound Cu_3Sn; but between the temperatures E′ and e this body may possibly not exist, and above e it certainly does not. This decomposition of the Cu_3Sn at or even before melting explains why the freezing-point curve has no summit corresponding to a body which almost certainly exists in the slowly cooled alloys. It would be worth while to examine the changes in the electrical resistance of these alloys when chilled.

Alloys containing somewhat more tin than Cu_3Sn go through similar changes as they cool. They solidify completely at temperatures that are not more than 30 or 40 degrees below their freezing point, the first matter solidifying being richer in copper than the alloy as a whole. When just solid the alloys appear to be uniform, and they remain so until their temperature falls to Roberts-Austen and Stansfield's curve, at which point a solid, that may be Cu_3Sn, crystallises out of the solid solution in long bars. These bars do not entirely fill the alloy, but are surrounded by mother substance which grows in bulk with increasing percentage of tin.

The structure of the chilled alloys shows many other interesting features which the authors hope to discuss at a future time.

Isomorphous Derivatives of Benzene.—Second Report of the Committee, consisting of Professor H. A. MIERS (*Chairman*), Dr. W. P. WYNNE, *and* Dr. H. E. ARMSTRONG (*Secretary*). (*Drawn up by the Secretary.*)

THE investigation of the 1 : 3 : 5 series of sulphonic chlorides and bromides derived from 1 : 3 dichloro-, dibromo- and chlorobromo-benzene has been continued during the past year and is almost completed. The results confirm and extend those previously arrived at, but also show that it will be necessary to study very carefully the dependence of the crystalline form on temperature and solvent. Progress has been made in preparing material for the examination of the 1 : 2 : 3 series, the third set to which the 1 : 3 di-derivatives can give rise; and the sulphonic derivatives of the 1 : 2 dichloro-, dibromo- and bromochloro-benzenes are also under investigation.

The crystallographical relationship of corresponding methyl-, ethyl-, propyl- and butyl-benzene sulphonic derivatives is also being made the subject of study, with a view to determine the alteration in crystalline form produced on introducing homologous hydrocarbon radicles into benzenesulphonic acid. The results thus far obtained show that a very thorough examination of the series will be required to bring to light the

real character of the relationship, which is apparently of a less simple character than that met with in the case of corresponding halogen derivatives.

On Wave-length Tables of the Spectra of the Elements and Compounds.—Report of the Committee, consisting of Sir H. E. Roscoe (*Chairman*), Dr. Marshall Watts (*Secretary*), Sir J. N. Lockyer, Professor J. Dewar, Professor G. D. Liveing, Professor A. Schuster, Professor W. N. Hartley, Professor Wolcott Gibbs, *and* Captain Sir W. de W. Abney.

Gold.

Ultra-violet Spark Spectrum.

Eder and Valenta, 'Denkschr. kaiserl. Akad. Wissensch. Wien,' lxviii. 1899.
Exner and Haschek, 'Sitzber, kaiserl. Akad. Wissensch. Wien,' cvii. 1898.

* Observed in the Arc-spectrum by Kayser and Runge.

† Wave-lengths enclosed within brackets are from Eder and Valenta's previous list of 1896.

Wave-length: Eder and Valenta	Wave-length: Exner and Haschek	Intensity and Character	Reduction to Vacuum: $\lambda +$	Reduction to Vacuum: $\frac{1}{\lambda}$	Oscillation Frequency in Vacuo
	4803·4	1b	1·31	5·7	20813
† (4792·79)	* 4792·79	4r	„	„	858·9
(60·34)	60·37	1n	1·30	5·8	21005·4
—	00·4	1n	1·29	5·9	275
(4683·84)	* 4683·77	1	1·28	„	344·4
(07·80)	07·72	3	12·6	6·0	696·7
(4587·91)	4588·0	1b	„	„	789
(59·05)	59·1	1b	1·25	6·1	960
(49·64)	49·7	1b	„	„	986
—	4499·1	1n	1·23	„	22221
(4488·43)	* 88·45	4r	„	6·2	273·2
—	75·7	1n	„	„	350
(37·37)	* 37·50	2r	1·22	„	529·0
—	31·3	1n	„	„	547
(20·69)	20·80	2r	1·21	6·3	623·2
(10·55)	10·5	1n	„	„	667
—	00·5	1n	„	„	718·7
(4395·72)	4395·6	1b	„	„	721
(15·34)	15·37	8r	1·18	6·4	23171·9
—	4278·0	1n	1·17	6·5	369
(4260·01)	60·06	2	„	„	477·3
(41·95)	* 42·00	2	1·16	6·6	567·1
—	26·89	2ca	„	„	651·4
(21·87)	22·00	1n	„	„	678·8
(4172·90)	4173·02	2	1·15	6·7	956·7
(4089·95)	4089·9	1b	1·12	6·9	24449
(84·31)	* 84·30	2	„	„	460·9

* 4792·79, 4488·46, 37·44, 4241·99, 4084·26.

GOLD—*continued.*

Wave-length		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Eder and Valenta	Exner and Haschek		λ+	1/λ −	
—	4083·49	2	1·12	6·9	24481·9
—	77·83	1	,,	,,	521·5
(4076·60)	76·52	1	,,	,,	523·8
(65·20)	* 65·25	15	,,	,,	591·8
—	61·2	1b	,,	,,	606
—	57·0	1b	,,	,,	642
(53·0)	53·01	7	1·11	,,	666·1
(41·07)	* 41·06	3s	,,	7·0	738·9
—	30·1	2b	,,	,,	801
(28·66)	28·63	1	,,	,,	815·3
(20·86)	20·87	1	,,	,,	863·0
(16·27)	16·28	5r	,,	,,	891·7
(12·87)	12·8	1n	1·10	,,	913
—	12·35	1n	,,	,,	916·3
—	02·6	1b	,,	7·1	999
(01·60)	01·7	1b	,,	,,	998
(3986·48)	3986·48	1	,,	,,	25077·8
(86·04)	86·1	1n	,,	,,	075
(79·72)	79·74	2n	,,	,,	120·1
(76·80)	76·77	2n	,,	,,	138·9
(59·35)	59·31	2	1·09	,,	249·8
(45·19)	45·2	1n	,,	7·2	328
—	33·80	4Ca	1·08	,,	425·0
(33·16)	33·1	1b	,,	,,	412
(27·82)	27·84	3	,,	,,	452·1
(16·15)	16·2	2b	,,	,,	516
(15·03)	14·93	1n	,,	,,	536·0
(09·60)	* 09·54	1s	,,	,,	571·2
(3898·03)	* 3898·1	10r	,,	7·3	641
—	90·56	1n	1·07	,,	695·9
(89·58)	89·61	1n	,,	,,	702·2
—	83·47	1	,,	,,	742·9
(80·34)	80·45	2	,,	,,	762·9
(77·45)	77·42	2	,,	,,	783·0
(74·96)	74·90	3	,,	,,	799·8
(65·70)	65·70	1n	,,	,,	861·2
—	60·8	1n	,,	,,	894
(59·53)	59·50	1n	,,	,,	902·8
(55·60)	55·52	1n	1·06	,,	929·5
(53·76)	53·72	2n	,,	,,	941·6
—	49·1	1n	,,	,,	973
—	47·62	1n	,,	,,	982·8
(45·02)	45·02	2n	,,	,,	26000·4
--	44·42	1n	,,	,,	004·4
—	42·8	1n	,,	[illegible]	015
(37·70)	37·7	1b	,,	[illegible]	050
—	36·62	1n	,,	,,	057·3
—	35·40	1n	,,	,,	065·6
—	32·50	1n	,,	,,	085·3
(31·31)	31·27	1n	,,	,,	093·7
(29·52)	29·60	1n	,,	,,	104·8
(28·56)	28·4	1b	,,	,,	114
(25·87)	25·87	3n	,,	,,	130·5
	24·5	1n	,,	,,	140
(23·20)	23·12	2n	,,	,,	149·3

* 4065·22, 41·07, 3909·54, 3898·04.

GOLD—*continued.*

Wave-length		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Eder and Valenta	Exner and Haschek		λ+	1/λ −	
(3822·11)	3822·05	3n	1·06	7·3	26156·7
(20·45)	20·40	1n	,,	,,	168·0
(16·50)	16·42	2n	1·05	7·4	195·1
—	10·07	1n	,,	,,	238·8
—	08·1	1b	,,	,,	246
(06·95)	07·1	1b	,,	,,	253
—	06·5	1b	,,	,,	263
(04·22)	04·20	5	,,	,,	267·0
(00·75)	00·50	1n	,,	,,	304·9
(3799·44)	3799·4	1n	,,	,,	312
—	98·15	1n	,,	,,	321·2
(96·15)	96·10	2n	,,	,,	335·4
—	95·4	1b	,,	,,	340
—	94·4	1b	,,	,,	347·2
—	93·0	1n	,,	,,	357
—	91·93	1	,,	,,	364·4
—	88·8	1n	,,	,,	390
(87·37)	87·4	1n	,,	,,	396
—	85·4	1n	,,	,,	410
(80·13)	80·14	2n	,,	,,	448·6
—	73·35	2	1·04	,,	494·0
(71·12)	71·1	1n	,,	7·5	504
(70·14)	70·1	1b	,,	,,	511
(65·76)	65·78	2	,,	,,	542·7
(65·10)	65·0	1n	,,	,,	553
(63·10)	63·1	1n	,,	,,	560
(59·03)	59·1	1b	,,	,,	595
(54·85)	54·8	1b	,,	,,	625
(52·90)	52·8	1b	,,	,,	639
(46·5)	46·1	1n	,,	,,	687
(32·68)	32·6	1n	1·03	,,	783
—	31·8	1n	,,	,,	789
(30·92)	31·0	1n	,,	,,	797
(18·02)	18·0	1n	,,	,,	887
—	14·2	1n	,,	7·6	916
—	09·8	1n	,,	,,	948
(08·30)	08·3	1n	,,	,,	959
(06·99)	06·96	3n	,,	,,	968·7
(02·49)	02·50	1n	,,	,,	27001·2
(3698·65)	3698·6	1b	,,	,,	030
(95·68)	95·6	1b	1·02	,,	052
(94·14)	94·1	1b	,,	,,	063
(90·18)	90·2	1b	,,	,,	091
(87·60)	87·6	1b	,,	,,	110
—	83·00	1n	,,	7·7	144·1
(81·39)	81·60	1n	,,	,,	154·4
—	80·9	1b	,,	,,	160
(77·62)	77·7	1b	,,	,,	183
(76·62)	76·6	1b	,,	,,	191
(75·11)	75·0	1b	,,	,,	203
(72·93)	72·9	1b	,,	,,	219
(71·34)	71·3	1b	,,	,,	231
(58·05)	58·2	1b	,,	,,	328
(57·35)	57·2	1b	1·01	,,	335
(54·56)	54·8	1n	,,	,,	354

GOLD—*continued.*

Wave-length		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Eder and Valenta	Exner and Haschek		λ+	1/λ –	
(3654·22)	3654·4	1n	1·01	7·7	27357
(53·93) (53·66)	53·70	2n	,,	,,	361·8
—	50·95	1	,,	,,	382·4
(49·25)	49·25	2n	,,	,,	395·2
—	45·1	1b	,,	,,	426
(42·66)	42·6	1b	,,	,,	445
(37·57)	37·6	1b	,,	7·8	483
(35·21)	35·35	2n	,,	,,	499·9
—	34·84	2	,,	,,	503·7
—	34·40	1	,,	,,	507·1
(33·40)	33·40	5s	,,	,,	514·6
(32·81)	32·8	1n	,,	,,	519
—	31·6	1n	,,	,,	528
(31·02)	31·0	1n	,,	,,	533
—	23·9	1n	,,	,,	587
(23·73)	23·6	1n	,,	,,	589
(22·93)	22·9	1n	,,	,,	594
—	20·5	1b	,,	,,	613
(14·17)	14·20	3nr	1·00	,,	660·8
—	09·74	2	,,	,,	695·0
(07·59)	07·70	2n	,,	,,	710·7
(04·94)	05·0	1n	,,	,,	731
(01·17)	01·22	2n	,,	,,	760·6
(3598·28)	3598·20	1n	,,	,,	783·9
(94·20)	94·31	1n	,,	7·9	813·9
(91·90)	92·03	1n	,,	,,	831·5
—	90·52	1n	,,	,,	843·2
(86·66)	86·84	5nr	,,	,,	871·8
(55·58)	55·5	2n	0·99	,,	28117·5
(53·72)	* 53·70	3n	,,	,,	131·8
—	51·65	1	,,	8·0	147·9
(49·26)	49·2	1b	,,	,,	167
(48·26)	48·20	1	,,	,,	175·3
(28·25)	28·1	2nr	0·98	,,	336
(23·42)	23·50	1	,,	,,	372·9
(3492·99)	3493·02	1n	0·97	8·1	620·4
(87·34)	87·33	1n	,,	,,	667·1
—	87·1	1n	,,	,,	669
—	81·35	1n	,,	,,	716·4
(70·47)	70·5	1n	,,	8·2	806
—	60·8	1n	,,	,,	887
—	57·05	1n	0·96	,,	918·2
(52·27)	52·4	1b	,,	,,	957
—	41·5	1n	,,		29049
—	21·37	1	,,	8·3	219·8
—	04·73	1	0·95	,,	362·6
—	04·05	1n	,,	,,	368·5
(3383·05)	3383·06	2	,,	8·4	550·6
—	82·6	1n	,,	,,	555
(82·26)	82·1	1n	,,	,,	559
(58·61)	58·5	1b	0·94	8·5	767
(55·35)	55·29	1	,,	,,	795·2
(08·36)	* 08·43	1	0·93	8·6	30217·2
(3230·72)	3280·85	2 A ʒ	0·92	8·7	47[illegible]

* 3553·72, 3308·42.

GOLD—*continued.*

Wave-length		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Eder and Valenta	Exner and Haschek		λ +	1/λ −	
(3273·84)	3274·1	1 Cu	0·92	8·7	30534
(65·18)	* 65·20	1	,,	,,	617·3
—	47·65	1	0·91	8·8	782·7
—	42·8	1n	,,	,,	829
(30·73)	* 30·76	2n	,,	,,	943·7
(28·0)	28·15	1n	,,	,,	968·7
(21·94)	22·0	1b	,,	,,	31028
(04·75)	* 04·8	1b	0·90	8·9	194
(3194·90)	*3194·9	1b	,,	,,	291
(56·73)	56·78	1	0·89	9·0	668·8
(22·88)	* 22·97	6	0·88	9·1	32011·7
—	22·63	5s	,,	,,	015·2
(3033·35)	*3033·3	1b	0·86	9·4	958
(29·32)	* 29·31	2	,,	,,	33001·4
(15·93)	15·97	1	0·85	9·5	147·3
—	2995·09	3	,,	9·6	378·4
—	90·42	4s	,,	,,	430·5
—	82·25	1	0·84	,,	522·1
(2954·64)	54·51	3	,,	9·7	836·9
(32·33)	* 32·32	2	0·83	9·8	34092·9
(18·48)	18·52	1n	,,	9·9	254·0
13·63*	13·68	9s	,,	,,	311·3
07·18	07·19	4s	,,	,,	387·6
06·07*	06·05	2n	,,	,,	400·9
2893·51	2893·56	3n	0·82	10·0	549·9
92·05*	92·07	2n	,,	,,	567·4
85·68	85·72	2	,,	,,	643·6
83·59*	83·57	3	,,	,,	669·1
64·63	64·6	1b	0·81	10·1	889
60·80	—	1n	,,	,,	945·2
57·04	57·00	2n	,,	,,	991·4
52·65	—	2b	,,	,,	35045·0
52·30	—	1n	,,	,,	049·3
47·23	47·20	3n	,,	10·2	111·8
38·16	38·13	5s	,,	,,	224·1
35·55	35·5	2s	,,	,,	257
33·16	33·17	2s	,,	,,	286·0
25·56	25·58	6s	,,	,,	380·9
22·87	22·85	5	0·80	10·3	414·9
20·11	20·11	9n	,,	,,	449·4
05·44	05·40	2	,,	,,	635·1
02·35	02·30	10s	,,	,,	674·5
2795·63	2795·73	2	,,	10·4	759·1
80·93	80·96	3s	0·79	,,	948·6
—	49·0	1n	,,	10·6	36366
48·35*	48·35	5s	,,	,,	374·9
45·80	—	1s	,,	,,	408·7
43·27	—	1s	,,	,,	442·2
32·14	32·10	2s	0·78	,,	591·0
21·96	21·94	2s	,,	10·7	727·7
—	06·13	1	,,	,,	942·4
03·44	03·51	2s	,,	,,	978·7
—	02·54	—	,,	10·8	991·4

* 3265·18, 30·73, 04·81, 3194·82, 22·88, 3033·38, 29·32, 2932·33, 2913·63, 2905·98, 2892·07, 2883·55, 2748·35r.

GOLD—*continued.*

Wave-length		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Eder and Valenta	Exner and Haschek*		$\lambda +$	$\frac{1}{\lambda} -$	
2701·01*	2701·03	3s	0·78	10·8	37012·2
2699·4	—	1n	,,	,,	034·5
97·8	—	1s	,,	,,	056
94·40*	—	2s	,,	,,	103·2
90·5	—	1n	,,	,,	157
88·80*	2688·82	4s	0·77	,,	180·2
88·26	88·26	3s	,,	,,	188·0
87·73	87·73	4s	,,	,,	195·3
86·0	—	1n	,,	,,	219
82·3	—	1n	,,	,,	271
76·08*	76·10	12s	,,	10·9	357·1
72·3	—	1	,,	,,	410
70·7	—	1	,,	,,	432·5
67·09	67·09	2s	,,	,,	483·1
65·28	65·25	2s	,,	,,	509·0
—	59·57	1s	,,	,,	589·2
51·2	—	1s	0·76	11·0	708
45·5	—	2b	,,	,,	789
41·65	41·56	6s	,,	,,	845·4
35·4	—	1n	,,	,,	934
34·4	—	1n	,,	,,	948
31·7	—	1n	,,	11·1	987
27·14	27·09	3s	,,	,,	38053·8
25·60	25·60	2s	,,	,,	075·4
24·2	—	2b	,,	,,	096
22·0	—	2n	,,	,,	128
17·58	17·48	2s	,,	,,	193·6
16·69	16·62	3n	,,	,,	206·1
12·8	—	1n	,,	,,	262
11·9	—	1n	,,	,,	275
10·36	10·4	1n	,,	,,	297
09·61	09·60	2b	0·75	,,	309·0
07·4	—	1n	,,	11·2	341
05·0	—	1n	,,	,,	377
2599·5	2599·5	2s	,,	,,	458
92·18	92·20	2s	,,	,,	566·1
90·18*	90·18	4s	,,	,,	596·2
83·5	—	2n	,,	11·3	696
80·1	—	1n	,,	,,	747
79·4	—	1n	,,	,,	757
77·7	—	1n	,,	,,	783
75·3	—	1n	,,	,,	819
71·4	—	2n	,,	,,	878
65·80	65·80	4s	,,	11·4	962·8
62·7	—	2s	0·74	,,	39010
61·9	—	1n	,,	,,	023
58·0	—	2n	,,	,,	082
52·92	52·9	2s	,,	,,	159·6
50·28	50·3	2s	,,	,,	199·8
44·29*	44·3	4s	,,	11·5	292·2
38·07	38·09	3n	,,	,,	388·4
37·0	—	2s	,,	,,	405
35·92	—	3s	,,	,,	421·9

* 2701·03, 2694·40, 2688·86, 2676·05r, 2590·19, 2544·30.

GOLD—*continued.*

Wave-length: Eder and Valenta	Wave-length: Exner and Haschek	Intensity and Character	Reduction to Vacuum: $\lambda +$	Reduction to Vacuum: $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
2533·70	2533·74	4s	0·74	11·5	39455·9
28·2	28·15	2s	„	11·6	543·0
22·8	—	2n	„	„	627
20·7	—	2s	„	„	660
17·2	—	2n	0·73	„	715
15·15	15·17	2s	„	„	747·1
11·7	—	1n	„	11·7	802
10·59*	10·59	4s	„	„	819·6
06·35	06·38	2s	„	„	886·5
—	06·07	1n	„	„	891·4
03·37	03·33	7s	„	„	934·8
2495·3	—	1s	„	„	40064
92·74	2492·68	2b	„	11·8	105·7
91·58	91·5	1s	„	„	123·4
90·49	90·5	2s	„	„	140·9
88·3	88·98	2s	„	„	165·3
83·4	—	2n	„	„	255
80·35	80·35	3s	„	„	305·1
78·59	78·68	1s	„	„	332·3
77·76	77·80	1s	„	„	346·6
76·2	76·10	3n	„	11·9	374·2
73·84	73·90	1n	„	„	410·0
68·06	68·05	2b	0·72	„	505·9
58·15	58·25	2s	„	12·0	667·3
56·55	—	2b	„	„	695·5
55·34	—	2b	„	„	715·6
52·79	—	2b	„	„	757·9
47·94	48·06	2s Ag	„	„	836·7
46·61	—	1n	„	„	860·9
—	46·20	1n	„	„	867·7
45·6	45·67	3b	„	„	876·6
44·3	—	1b	„	„	900
42·47	42·48	2b	„	12·1	929·9
37·83	37·89	3s Ag	„	„	41007·0
34·5	—	1n	„	„	064
33·67	33·7	2	„	„	078·2
33·3	—	2s	„	„	084
28·06*	28·10	15r	„	12·2	172·3
—	25·05	1n	„	„	224·1
23·8	—	2	„	„	246
19·41	19·4	1n	0·71	„	320·1
19·1	—	1	„	„	327
17·4	—	2	„	„	355
16·68	16·7	2b	„	„	367·9
14·36	—	1n	„	„	406·6
13·27	13·31	3s	„	„	424·7
11·40	11·50	2s	„	12·3	455·7
10·7	—	1s	„	„	470
08·89	—	2n	„	„	500·6
07·42	—	2n	„	„	525·9
05·20	05·24	3s	„	„	563·6
04·97	04·95	2s	„	„	568·6
02·80	02·83	3s	„	„	605·3

* 2510·56, 2428·06r.

GOLD—*continued.*

Wave-length		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Eder and Valenta	Exner and Haschek		$\lambda +$	$\frac{1}{\lambda} -$	
2401·63	2401·68	2s	0·71	12·3	41625·2
—	01·3	1n	,,	,,	632
00·2	—	1 Cu	,,	,,	651
2399·3	—	1	,,	,,	666
95·7	—	1	,,	12·4	729
93·62	2393·66	2s	,,	,,	764·6
91·7	—	1n	,,	,,	799
88·26	88·35	3s	,,	,,	857·5
87·82*	87·84	4s	,,	,,	866·5
84·29	—	2s	,,	,,	928·8
82·50	82·51	3b	,,	12·5	960·0
80·5	—	1n	,,	,,	42095
79·3	—	1s	,,	,,	017
—	78·0	1n	,,	,,	040
77·2	77·3	1	,,	,,	053
76·35	76·31	4s	,,	,,	069·6
73·20	—	2n	0·70	,,	124·7
71·69	71·67	4s	,,	,,	151·9
69·40	69·46	4n	,,	,,	174·0
—	68·10	1	,,	12·6	215·3
65·01	64·99	6r	,,	,,	270·9
64·68	64·64	3s	,,	,,	277·1
59·1	—	1n	,,	,,	376
57·9	58·02	1n	,,	,,	395·9
55·53	[illegible]·57	2s	,,	,,	440·3
52·67*	52·81	5s	,,	12·7	490·9
51·59	51·61	2s	,,	,,	511·4
48·2	—	1s	,,	,,	573
47·10	47·23	2s	,,	,,	592·0
44·25	—	2s	,,	,,	644·9
43·6	—	2s	,,	,,	656
42·81	—	1	,,	,,	671·1
41·5	—	1	,,	,,	695
40·27	40·30	7b	,,	12·8	716·8
34·20	34·15	2b	,,	,,	829·3
—	32·00	2n	,,	,,	868·9
31·45	31·46	2s	,,	,,	878·8
31·20	—	4s	,,	,,	883·6
30·7	—	1s	,,	,,	893
26·7	26·8	1n	,,	12·9	964·6
25·77	25·80	2s	0·69	,,	983·1
25·34	25·32	2	,,	,,	991·9
24·7	24·73	1s	,,	,,	43002·8
22·34	22·39	7s	,,	,,	046·2
21·4	—	1s	,,	,,	064
20·35	20·37	2s	,,	,,	083·7
18·28	18·39	2	,,	,,	120·5
17·5	17·10	1s Ag	,,	,,	144·5
15·94	15·96	6s	,,	,,	165·7
14·73	14·77	6s	,,	,,	187·9
12·2	12·3	2	,,	13·0	234
—	11·06	1	,,	,,	257·2
09·54	09·50	6s	,,	,,	286·4
08·2	08·26	1	,,	,,	309·7
04·89	04·90	9b	,,	,,	372·8

2387·85, 2364·69, 2352·75.

GOLD—*continued.*

Wave-length		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Eder and Valenta	Exner and Haschek		λ+	$\frac{1}{\lambda}$ –	
2301·1	2301·15	1n	0·69	13·1	43443·4
00·4	—	1s	,,	,,	458
2298·3	—	1n	,,	,,	497
96·9	2296·92	2s	,,	,,	523·5
—	96·62	1	,,	,,	529·2
95·18	95·20	3s	,,	,,	556·1
94·08	94·1	2b	,,	,,	577
91·59	91·60	6b	,,	,,	624·5
88·70	88·66	2s	,,	,,	680·6
87·79	87·85	3n	,,	13·2	696·0
86·7	86·80	1n	,,	,,	716·0
83·37 *	83·38	5s	,,	,,	779·5
82·95	82·94	3n	,,	,,	890·0
—	80·05	1n Ag	,,	,,	845·5
79·42	79·40	2n	,,	,,	858·0
—	78·10	1	,,	,,	883·0
77·62	77·65	4n	0·68	,,	889·7
73·2	73·25	1s	,,	13·3	976·6
70·3	70·27	2s	[illegible]	,,	44034·3
67·03	67·07	2s	[illegible]	,,	096·5
66·20	66·01	3b	[illegible]	,,	117·1
65·3	65·10	1n	[illegible]	[illegible]	134·9
63·75	63·77	3n	[illegible]	,,	160·8
62·68	62·70	3	[illegible]	13·4	181·6
61·32	61·35	2n	[illegible]	,,	208·0
60·36	—	2n	[illegible]	,,	227·3
55·90	55·95	2n	[illegible]	,,	313·8
55·00	55·1	1n	[illegible]	,,	331
53·44	53·48	3s	[illegible]	,,	362·4
—	49·13	1	[illegible]	13·5	448·1
48·70	48·77	2n	,,	,,	455·3
46·76	46·70	3n	,,	,,	496·2
—	46·50	1	,,	,,	500·2
—	45·53	1	,,	,,	519·4
43·6	44·01	1n	,,	,,	549·6
42·71	42·78	5s	,,	,,	574·0
—	42·00	—	,,	,,	589·5
40·36	40·35	3	,,	,,	622·4
37·56	37·55	2n	,,	13·6	678·1
33·75	33·75	2n	,,	,,	754·2
31·37	31·40	4n	,,	,,	801·3
29·09	29·07	6n	,,	,,	848·2
—	24·7	1n	0·67	13·7	936
22·64	22·70	2n	,,	,,	976·6
20·64	20·62	3s	,,	,,	45018·8
19·4	19·25	2	,,	,,	046·6
15·85	15·80	3n	,,	,,	116·7
13·20	13·25	4s	,,	13·8	168·6
10·64	10·73	3s	,,	,,	220·1
10·30	10·27	1s	,,	,,	229·5
05·92	05·97	2s	,,	,,	317·7
01·35	01·42	5s	,,	,,	45411·3
2193·7	2193·55	1	,,	,,	574·3
92·7	—	1s	,,	,,	592·0
90·7	90·57	1s	,,	14·0	636·2

* 2283·42.

GOLD—*continued.*

Wave-length		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Eder and Valenta	Exner and Haschek		λ +	$\frac{1}{\lambda}$ –	
2188·97	2189·03	4s	0·67	14·0	45668·3
86·9	86·80	2	,,	,,	714·9
85·7	85·65	2s	,,	,,	739·0
84·15	84·21	2s	,,	,,	769·1
72·26	72·28	2s	0·66	14·1	46020·5
67·5	67·40	2s	,,	14·2	124·0
—	61·27	1n	,,	,,	254·9
60·7	60·55	2n	,,	,,	270·3
59·2	59·13	2n	,,	14·3	300·7
57·18	57·21	2n	,,	,,	341·9
54·4	54·30	2n	,,	,,	404·5
—	44·27	1	,,	14·4	621·5
40·5	40·5	1n	,,	,,	704
37·95	37·95	2b	,,	,,	759·4
33·4	33·3	1b	,,	14·5	860
—	29·57	1	0·65	,,	943·3
29·03	—	1s	,,	,,	955·2
26·8	26·73	2s	,,	14·6	47003·9
25·28	25·32	4s	,,	,,	037·1
13·7	13·69	1s	,,	14·7	295·9
10·74	10·78	6s	,,	,,	361·1
2098·8	—	1n	,,	14·8	631
98·2	2098·18	1s	,,	,,	645·6
95·0	—	1n	,,	14·9	718
85·4	—	1	,,	15·0	937
83·1	83·16	1s	,,	,,	48989·0
82·10	82·16	5s	,,	,,	012·7
71·7	—	1	0·64	15·1	255
64·0	—	1	,,	15·2	434
59·9	—	1	,,	,,	531
56·6	—	1	,,	,,	609
55·4	—	1	,,	15·3	637
44·65	44·70	5s	,,	15·4	891·5
12·10	—	1n	0·63	15·7	49683·6
00·77	00·9	3s	,,	15·8	965·0
1988·99	—	1s	,,	16·0	50260·8
77·59	1977·6	1	,,	16·1	550
72·66	—	1	0·62	,,	676·9
55·64	—	1	,,	16·3	51117·9
51·59	—	3	,,	16·4	223·9
48·48	—	1	,,	,,	305·7
46·41	—	1	,,	,,	360·2
44·35	—	1	,,	16·5	414·6
35·13	—	1b	,,	16·6	659·5
31·74	—	3	,,	,,	750·2
25·19	—	2	0·61	16·7	926·2
21·38	—	8	,,	,,	52029·2
19·39	—	6	,,	16·8	083·1
18·04	—	1	,,	,,	119·8
04·41	—	1	,,	16·9	492·8
1890·25	—	2	,,	17·2	885·9
86·85	—	2	,,	,,	981·2
79·72	—	1	,,	17·3	53182·1
61·68	—	2	0·60	17·5	697·4

Manganese (Arc Spectrum).

Hasselberg: 'Kongl. Svenska Vetenskaps-Akadem. Handl.,' Bd. xxx., No. 2. 1897.

* Coincident with Fraunhofer lines.

‡ These lines seem not to occur in Exner and Haschek's list of manganese spark lines, Sitzber, 'Kais. Akad. Wissensch. Wien.' civ. (1895), cv. (1896). This list includes 1,550 lines, extending from 4824 to 2112. Within these limits all the lines of the arc spectrum not marked ‡ seem to occur.

Wave-length (Rowland)	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
*5849·33	2		1·59	4·6	17091·4
17·15	2		,,	4·7	185·8
*5780·42	3		1·58	,,	295·1
* 38·49	4	5787·910 Rowland	1·56	,,	421·5
5573·94	5		1·52	4·9	935·7
* 73·27	4		,,	,,	937·9
56·09	2		,,	,,	993·4
52·75	2		1·51	,,	18004·2
52·24	5	5552·193	,,	,,	005·8
* 38·07	7	38·025, 37·928		,,	051·9
* 35·77	4			,,	054·4
* 17·05	7	5517·03 Thalén, 17·034, 16·950		,,	120·7
15·06	2			,,	127·3
* 06·15	5	06·095	1·50	5·0	164·5
04·53	3			,,	166·8
5497·67	2			,,	184·5
96·23	2			,,	189·3
81·67	6			,,	237·6
* 70·86	7	5470·883, 70·802 ,,	1·49	,,	273·7
* 57·71	4	57·701 ,,	,,	,,	317·7
33·67	4n		1·48	,,	398·8
* 32·75	5	32·753 ,,	,,	,,	401·9
* 20·58	4	5420·50 ,, 20·613, 20·510 ,,	,,	,,	443·2
* 13·94	5	13·70 ,, 13·889 ,,	,,	,,	465·8
* 07·63	7	07·80 ,, 07·688, 07·587 ,,	,,	,,	487·4
06·32	2		,,	,,	495·3
*5399·72	6	00·85 ,, 5399·675 ,,	1·47	5·1	514·4
* 94·88	6	5394·75 ,, 94·918, 94·839 ,,	,,	,,	531·0
* 88·76	3		,,		552·0
* 77·83	6	77·85 ,, 77·800 ,,	,,	,,	589·8
77·46	3		,,	,,	591·0
* 50·08	4	50·059 ,,	1·46	,,	686·2
48·31	2		,,	,,	712·4
* 44·66	3n	44·646 ,,	,,	,,	705·2
* 41·22	9	41·45 ,, 41·337 ,,	,,	,,	717·2
24·53	3		1·45	,,	775·9
17·33	2		,,	,,	801·3
09·16	3n		,,	,,	850·3
5299·09	2		,,	5·2	866·0
98·13	2		,,	,,	869·4

MANGANESE (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Observations (Rowland)				Reduction to Vacuum		Oscillation Frequency in Vacuo
						λ+	1/λ −	
5261·00	2					1·44	5·2	19002·6
* 55·51	5s	5255·51	Thalén,	5255·492	Rowland	,,	,,	022·4
*5197·44	2s	5197·01	,,	5197·332	,,	1·42	5·3	235·0
* 96·77	5s			96·741	,,	,,	,,	237·4
* 51·14	5s			51·112	,,	1·41	,,	407·9
* 49·40	3			18·112	,,	,,	,,	414·4
* 18·15	4					1·40	,,	532·9
*5087·02	2					1·39	5·4	652·5
* 74·97	4					,,	,,	699·1
42·86	2					1·38	,,	824·6
30·86	2					,,	,,	871·9
* 30·02	3					,,	,,	875·2
22·26	2n					1·37	5·5	905·8
* 10·58	3					,,	,,	952·2
* 05·10	4s			5005·347	,,	,,	,,	974·1
4985·98	3					1·36	,,	20050·7
74·60	3n					,,	,,	096·6
* 66·02	5s			4966·036	,,	,,	,,	131·3
* 34·25	5s					1·35	5·6	260·9
01·00	2					1·34	,,	398·4
4889·12	2					,,	,,	447·0
* 81·87	2					,,	,,	478·3
62·28	4					1·33	,,	560·9
* 55·01	2					,,	5·7	591·6
* 54·76	3					,,	,,	592·6
* 44·47	4			4844·408	,,	,,	,,	636·4
* 38·40	2					1·32	,,	662·3
* 27·10	2					,,	,,	710·7
* 25·80	2					,,	,,	716·2
* 23·71	10n r	4823·60	,,	23·715	,,	,,	,,	725·2
*4783·60	10n r	4783·84	,,	4783·607	,,	1·31	5·8	898·9
* 66·58	7	66·14	,,	66·621	,,	1·30	,,	973·6
* 66·02	7	65·64	,,	66·050	,,	,,	,,	976·0
* 62·54	8	62·14	,,	62·567	,,	,,	,,	991·4
* 61·68	7	61·34	,,	61·718	,,	,,	,,	21995·2
* 54·23	10n r	54·04	,,	54·225	,,	,,	,,	028·1
* 39·27	6s	39·14	,,	39·291	,,	,,	,,	094·5
* 27·63	7	27·64	,,	27·676	,,	1·29	,,	146·4
* 09·87	7	09·94	,,	09·896	,,	,,	,,	226·2
* 01·30	4	01·14	,,	01·345	,,	,,	5·9	262·0
*4671·86	4s	4671·58	,,	4671·858	,,	1·28	,,	398·8
* 43·01	2					1·27	,,	531·8
27·99	2					,,	6·0	601·6
* 26·74	4s	26·48	,,	26·718	,,	,,	,,	607·5
07·80	3n	07·48	,,			1·26	,,	695·9
* 05·55	5n	05·68	,,	05·536	,,	,,	,,	706·9
4595·51	3					,,	,,	754·4
86·30	2					,,	,,	798·1
48·75	4	4549·05	,,			1·25	6·1	978·0
44·61	3					,,	,,	998·0
* 42·62	4					1·24	,,	22007·6
34·72	2					,,	,,	046·0
30·01	2					,,	,,	068·9
* 23·58	3			4523·572	,,	,,	,,	100·3
04·03	4	03·95	,,	04·042	,,	1·23	,,	196·2

MANGANESE (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Observations (Rowland)				Reduction to Vacuum		Oscillation Frequency in Vacuo
						λ+	$\frac{1}{\lambda}-$	
*4502·38	7	4502·45	Thalén,	4502·388	Rowland	1·23	6·1	22204·4
*4499·06	7	4499·05	,,	4499·070	,,	,,	,,	220·8
* 96·82	3	96·05	,,	96·676	,,	,,	6·2	231·7
* 91·86	4	91·85	,,	91·823	,,	,,	,,	258·3
* 90·28	7	90·25	,,	90·253	,,	,,	,,	264·1
* 79·59	4	79·75	,,	79·553	,,	,,	,,	317·3
* 72·92	6	73·15	,,	72·967	,,	,,	,,	350·6
* 70·31	6	{71·85 / 70·25	,, / ,,	70·300	,,	,,	,,	363·6
* 64·86	7	65·05	,,	64·844	,,	1·22	,,	390·9
* 62·17	8n	62·25	,,	62·165	,,	,,	,,	404·4
* 61·25	7	61·41	,,	61·242	,,	,,	,,	409·0
60·55	5	60·55	,,	60·462	,,	,,	,,	412·6
* 58·43	7	58·45	,,	58·409	,,	,,	,,	423·2
* 57·71	6	57·65	,,	57·712	,,	,,	,,	426·8
* 57·22	6	57·45	,,	57·207	,,	,,	,,	429·1
* 56·05	6	56·15	,,	55·980	,,	,,	,,	435·2
* 55·50	6	55·55	,,	55·485	,,	,,	,,	438·0
* 55·19	6	55·25	,,	55·198	,,	,,	,,	440·0
* 53·16	6	53·25	,,	53·171	,,	,,	,,	450·3
52·73‡	3					,,	,,	452·4
* 51·75	7	51·95	,,	51·752	,,	,,	,,	456·9
* 47·32	3	47·45	,,	47·302	,,	,,	,,	479·2
* 36·52	6	36·45	,,	36·516	,,	,,	,,	534·0
36·24	3					,,	,,	535·4
* 19·96	4s	20·05	,,	19·944	,,	1·21	6·3	618·3
* 15·06	6	15·05	,,	15·047	,,	,,	,,	638·6
* 12·06	4	12·15	,,	12·043	,,	,,	,,	658·8
* 08·28	3	08·35	,,			,,	,,	678·3
4389·95	3			4389·930	,,	1·20	,,	773·0
88·27	?			88·260	,,	,,	,,	781·7
82·80	3n	4383·10	,,	82·847	,,	,,	,,	810·2
81·87	4	82·30	,,	82·045	,,	,,	,,	815·0
* 75·10	4	75·30	,,	75·103	,,	,,	,,	850·3
37·57	2			37·569	,,	1·19	6·4	23048·0
26·35	—	26·10	,,			,,	,,	107·8
23·59	—	23·50	,,			,,	,,	122·5
21·36	—	21·40	,,			,,	,,	134·5
* 12·70	5			12·723	,,	1·18	,,	180·9
05·84	2					,,	6·5	217·8
00·35	3	00·23	,,	00·376	,,	,,	,,	247·4
4290·29	2					,,	,,	301·9
* 84·22	5	4284·53	,,	4284·223	,,	,,	,,	335·0
* 81·27	6	81·33	,,	81·257	,,	,,	,,	351·0
78·85	3					1·17	,,	364·2
* 66·08	6	66·33	,,	66·081	,,	,,	,,	434·2
* 61·45	3	61·63	,,	61·496	,,	,,	,,	459·7
* 58·48‡	2					,,	,,	476·0
* 57·80	6	58·03	,,	57·815	,,	,,	,,	479·8
* 39·88	6	40·08	,,	39·890	,,	1·16	6·6	579·0
* 35·45‡	6	35·42	,,	35·450	,,	,,	,,	603·6
* 35·28	6			35·298	,,	,,	,,	604·6
30·47‡	2					,,	,,	631 4
30·31	2					,,	,,	632·3
* 20·79	5	21·13	,,	20·738	,,	,,	,,	685·6

MANGANESE (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Observations (Rowland)				Reduction to Vacuum λ+	Reduction to Vacuum 1/λ −	Oscillation Frequency in Vacuo
*4212·64‡	2					1·16	6·6	23731·5
* 11·90	4			4211·899	Row'and	,,	,,	735·6
* 01·88	4	4202·23	Thalén,	01·869	,,	1·15	,,	792·3
*4190·15	4			4190·147	,,	,,	6·7	858·8
* 76·73	5			76·739	,,	,,	,,	935·5
* 57·21	3			57·167	,,	1·14	,,	24048·5
55·68‡	3					,,	,,	056·7
* 51·16	3					,,	,,	082·9
* 48·94	5			48·948	,,	,,	6·8	095·7
* 47·65	4			47·645	,,	,,	,,	103·2
* 41·18	5			41·208	,,	,,	,,	140·9
* 40·35	2					,,	,,	145·7
* 37·40‡	4			37·428	,,	,,	,,	163·0
* 35·13	5	4135·26	,,	35·191	,,	,,	,,	175·2
34·77	4					,,	,,	178·8
32·45	2					,,	,,	188·7
31·60‡	2					,,	,,	201·9
* 31·26	5			31·271	,,	,,	,,	203·9
* 23·68	3			23·664	,,	1·13	,,	243·4
* 23·41	3					,,	,,	245·0
22·92	3					,,	,,	247·8
14·53	4			14·461	,,	,,	,,	297·3
* 14·02	3s					,,	,,	300·3
* 13·39	4			13·381	,,	,,	,,	304·0
* 10·98	6			11·021	,,	,,	,,	318·3
* 08·01	3					,,	,,	335·9
* 05·51	5			05·514	,,	,,	,,	350·7
* 03·62	3					,,	,,	361·9
* 03·07	4			03·097	,,	,,	,,	365·2
4099·57	2					,,	6·9	386·0
* 96·81‡	3					,,	,,	402·2
* 95·42	4			4095·423	,,	,,	,,	407·2
95·17	2					,,	,,	412·0
90·73	2					1·12	,,	438·6
90·10	4			90·113	,,	,,	,,	442·3
* 83·75	9	4083·83	,,	83·783	,,	,,	,,	480·4
* 83·09	9	83·13	,,	83·095	,,	,,	,,	484·4
* 79·56‡	9	79·48	,,	79·570	,,	,,	,,	505·5
* 79·35	9			79·393	,,	,,	,,	506·5
* 75·39	3			70·431	,,	,,	,,	530·6
* 70·41	6			68·137	,,	,,	,,	560·6
* 68·13	4s also Fe					,,	,,	574·4
66·38	3			65·239	,,	,,	,,	585·0
* 65·22	4					,,	,,	593·3
* 63·38	7 also Fe	63·63	,,	63·573	,,	,,	,,	603·2
* 61·88	6			61·881	,,	,,	,,	612·2
* 59·53	6			59·535	,,	,,	,,	626·5
* 59·08	7			59·081	,,	,,	,,	629·2
* 58·10	5			58·115	,,	,,	,,	635·2
* 55·68	9	56·43	,,	4055·701	,,	,,	,,	649·9
55·35‡	4			55·365	,,	,,	,,	651·9
* 52·62	4			52·603	,,	1·11	,,	668·5
51·90	4					,,	7·0	672·8
* 49·16‡	4					,,	,,	689·5
* 48·88	8	48·83	,,	4048·910		,,	,,	691·2

MANGANESE (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum λ+	Reduction to Vacuum 1/λ −	Oscillation Frequency in Vacuo
*4045·26	6	4045·266 Rowland	1·11	7·0	24713·3
* 41·49	10n also Fe	4041·23 Thalén, 41·525 ,,	,,	,,	736·3
38·89‡	4	38·771 ,,	,,	,,	752·3
* 35·88	6	4035·883 ,,	,,	,,	770·7
* 34·60	20n r	34·68 ,, 34·644 ,,	,,	,,	778·6
* 33·18	20n r	33·53 ,, 33·230 ,,	,,	,,	787·3
* 30·87	20n r	30·13 ,, 30·919†	,,	,,	801·5
* 26·57	6	26·583	,,	,,	828·0
* 20·18	3	20·226	,,	,,	867·5
* 18·25	7	18·25 †	,,	,,	879·4
12·09	2		1·10	,,	917·6
11·69	3	11·693	,,	,,	920·1
08·19	3	08·215	,,	,,	941·9
03·42	2		,,	7·1	971·5
02·31‡	2	02·308	,,	,,	978·5
02·05	2	02·086	,,	,,	980·1
3997·34	2	3997·365	,,	,,	25009·5
92·65	3	3992·5 Lockyer	,,	,,	038·9
* 90·10	2	90·0 ,, 90·129	,,	,,	054·9
87·61	2	87·625	,,	,,	070·6
* 87·23	4	3987·244	,,	,,	073·0
* 86·94	4	86·979	,,	,,	074·8
* 85·36	4	85·463	,,	,,	084·7
84·31	2	3984·294	,,	,,	091·3
83·07‡	2	83·053	,,	,,	099·2
* 82·72	4	82·680	,,	,,	101·4
82·31	2		,,	,,	103·0
77·24	3	77·2 ,, 77·223	,,	,,	136·1
* 76·03	3	75·6 ,, 75·983	,,	,,	143·5
53·00	4	52·7 ,, 53·043	1·09	7·2	290·0
43·01	3n	43·0 ,, 42·984	,,	,,	354·1
36·91	2	36·912	,,	,,	393·4
29·82	2	29·6 29·864	1·08	,,	439·3
29·41	—		,,	,,	441·9
* 29·30‡	3	29·363	,,	,,	442·6
* 26·61	5	26·5 ,, 26·597	,,	,,	459·1
* 24·24	4	24·2 ,, 24·206	,,	,,	480·4
* 23·45	3	23·5 ,, 23·375	,,	,,	480·6
* 22·82‡	5n	22·8 ,, 22·815	,,	,,	484·7
* 22·20	2	22·223	,,	,,	488·7
* 21·85‡	4n	21·8 ,, 21·855	,,	,,	491·0
* 18·43	4	18·3 ,, 18·396	,,	,,	513·2
16·75	2	16·661	,,	,,	524·2
11·57	3	11·5 ,, 11·554	,,	,,	558·0
11·27	3n	11·2 ,,	,,	,,	559·9
08·34	2s		,,	7·3	579·0
05·12	2		,,	,,	600·1
04·47	2		,,	,,	604·9
03·68	2		,,	,,	616·1
3899·81‡	4s	3899·701 ,,	,,	,,	635·0
99·46	3s	99·530 ,,	,,	,,	637·2
* 98·50	4	98·531 ,,	,,	,,	643·5

* double $\begin{cases} 4030·497 \\ 30·878 \end{cases}$ † $\begin{cases} 4018·269 \\ 18·234 \end{cases}$

MANGANESE (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
3897·47	2		1·08	7·3	25650·4
96·48	3s	3896·385 Rowland	1·07	,,	656·9
* 94·85	3s	94·850 ,,	,,	,,	667·6
* 92·72	2	92·698 ,,	,,	,,	681·7
* 91·92	3		,,	,,	687·0
89·62	2	89·498 ,,	,,	,,	699·9
* 86·42	5s also Fe		,,	,,	727·3
79·32	2		,,	,,	770·4
72·26	2		,,	,,	817·4
65·83	2		,,	,,	860·4
* 61·88‡	3		,,	,,	886·8
56·68	4		,,	,,	921·7
* 53·60	3		1·06	,,	942·5
* 44·10	7	44·135 ,,	,,	,,	26006·6
* 41·17	8 also Fe	41·195 ,,	,,	,,	026·4
* 39·92	7	39·922 ,,	,,	,,	034·9
37·68	3		,,	,,	050·1
* 34·48	9	34·506 ,,	,,	,,	071·8
* 33 96	7	34·006 ,,	,,	,,	075·4
30·12‡	2		,,	,,	101·5
* 29·81	5		,,	,,	103·6
* 24·01	7	24·028 ,,	,,	,,	143·3
* 23·64	8	23·653 ,,	,,	,,	145·8
* 16·87	5	16·887 ,,	1·05	7·1	192·1
10·85	4		,,	,,	233·5
09·70	6	09·733† ,,	,,	,,	239·5
* 06·84	9 also Fe	06·865 ,,	,,	,,	261·1
02·04	4	02·051 ,,	,,	,,	294·3
* 00·68	4	00·683 ,,	,,	,,	303·7
*3799·38	4	3799·386 ,,	,,	,,	312·7
* 90·36	6	90·362 ,,	,,	,,	375·3
* 85·57	3		,,	,,	408·7
* 76·70	3s	76·698 ,,	1·04	,,	470·7
* 74·81	2		,,	,,	484·0
* 74·02	2		,,	,,	489·5
71·62	2		,,	7·5	506·3
68·33	2		,,	,,	529·4
* 67·84	4	67·787 ,,	,,	,,	532·9
63·51	4		,,	,,	563·4
* 56·80	3	56·705 ,,	,,	,,	610·9

† Double $\begin{cases} 3809·834 \\ 09·633. \end{cases}$ Rowland's Table of Solar Spectrum Wave-lengths gives the following lines (not mentioned in the above list) as due to Manganese: 5457·640, 12·997, 5321·976, 4884·242, 4233·328, 4171·854, 4092·747, 83·376, 45·371, 33·814, 33·732, 31·942, 07·185, 3954·680, 52·103, 37·972, 3895·583, 88·971, 40·340, 3696·800, 95·658, 91·452, 84·680, 58·689, 58·044, 17·575, 15·531, 3590·109, 11·763, 3488 437, 87·095, 74·287, 74·197, 60·174, 55·204, 55·121, 51·609, 42·118, 20·940, 3386·085, 82·825, 82·129, 79·005, 70·770, 69·352, 68·319, 55·661, 45·495, 43·804, 30·802, 20·783, 17·393, 16·698, 16·561, 14·995, 14·574, 14·334, 13·562, 13·301, 12·063, 08·888, 07·114, 05·001, 03·398, 3299·652, 98·361, 97·014, 95·951, 80·900, 78·687, 73 175, 70·473, 68·847, 64·833, 60·386, 58 542, 56·264, 55·617, 54·180, 53·090, 51·273, 48·637, 43·883, 40·726, 40·522, 36·905, 30·843, 28·219, 26·143, 24·882, 17·040, 13 004, 3178·620, 67·289, 61 146, 48·283, 42·846, 40·430, 3079·724, 73·232, 70·372, 66·101, 62·222, 54·429, 48·999, 47·156, 45·695, 44·671, 40·712, 22·861, 2801·183, 2798·369, 94·911, 2593·810, 76·195.

MANGANESE (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
3750·92	4	3750·916 Rowland	1·04	7·5	26652·6
49·54	3		,,	,,	662·4
46·78	4	46·717 ,,	,,	,,	682·1
* 37·03	3	37·059 ,,	1·03	,,	751·7
32·05	5	32·072 ,,	,,	,,	787·4
* 29·05	4	29·004 ,,	,,	,,	809·0
27·21‡	2	27·061 ,,	,,	7·6	822·1
* 19·04	5	19·070 ,,	,,	,,	881·1
* 06·16	5	06·175 ,,	,,	,,	974·5
* 01·85	3s	01·866 ,,	,,	,,	27005·9
* 00·47	2		,,	,,	016·0
*3696·69	5	3696·707 ,,	1·02	,,	044·6
94·28	3n		,,	,,	061·3
* 93·81	5	93·804 ,,	,,	,,	064·7
* 92·98	3	92·954 ,,	,,	,,	070·8
* 85·69‡	2	85·665 ,,	,,	,,	124·4
85·04	2		,,	,,	129·1
* 82·24	4	82·161 ,,	,,	7·7	149·7
80·32	2		,,	,,	163·8
* 77·12	4		,,	,,	187·5
* 70·67	3	70·678 ,,	,,	,,	235·3
* 70·00	2	69·976 ,,	,,	,,	240·3
* 69·54	2		,,	,,	243·7
* 60·52	4	60·549 ,,	,,	,,	310·8
* 41·60	2	41·597 ,,	1·01	7·8	452·6
35·89	2		,,	,,	495·8
* 29·87	4	29·877 ,,	,,	,,	541·4
* 23·92	5	23·926 ,,	,,	,,	586·6
* 19·42	6	19·412 ,,	,,	,,	620·9
* 10·44	6	10·435 ,,	1·00	,,	689·6
* 08·62	6	08·630 ,,	,,	,,	703·6
* 07·66	6	07·672 ,,	,,	,,	711·0
01·96	2		,,	,,	754·9
01·45	2		,,	,,	758·8
*3595·25	5	3595·256 ,,	,,	,,	806·7
* 86·65	6	86·684 ,,	,,	,,	873·3
* 77·99	7	78·014 ,,	0·99	7·9	940·7
* 70·18	5n	70·183 ,,	,,	,,	28001·9
* 69·91	5n	69·958 ,,	,,	,,	004·0
* 69·66	8n	69·649 ,,	,,	,,	006·0
* 48·35‡	5n	48·332 ,,	,,	,,	174·1
* 48·17	5n	48·175 ,,	,,	8·0	175·5
* 47·94	5n	47·941 ,,	,,	,,	177·4
* 32·27	5n	32·262 ,,	0·98	,,	302·4
* 32·14	5n	32·143 ,,	,,	,,	303·4
* 31·97	5n	31·982 ,,	,,	,,	304·8
*3497·67	3	97·668 ,,	0·97	8·1	582·3
* 96·96	3	96·952 ,,	,,	,,	588·2
* 95·99	4	95·974 ,,	,,	,,	596·1
* 88·80	4	88·817 ,,	,,	,,	655·0
* 83·01	4	83·047 ,,	,,	,,	702·7
* 60·47	5	60·460 ,,	,,	8·2	889·6

Silicon (Spark Spectrum).

Eder and Valenta, 'Sitzber. kais. Akad. Wissensch. Wien,' cvii. (2), 1898.
Exner and Haschek, *ibid.*, cviii. (2), 1899.
Lockyer, 'Proc. Royal Soc.,' lxv. p. 449. 1900.

† Observed also by Count de Gramont, who gives also lines at 6969·7, 6342·2, 5978·9, 5960·3, 5948·0 ?, 5060·0, 5045·5.

* Observed also by Rowland, whose values are 4103·101, 3905·666, 2987·766, 2881·695, 2631·392, 2528·599, 2524·206, 2519·297, 2516·210, 2514·417, 2506·994, 2413·460, 2438·864, 2435·247, 2216·760, 2211·759, 2210·939, 2208·060. Rowland gives also lines at 5948·761, 5771·360, 5708·620, 5645·835, and 2218·146.

‡ 3807 Lunt, 'Astroph. J.' xi. p. 269 (1900).

Eder and Valenta		Exner and Haschek		Lockyer	Reduction to Vacuum		Oscillation Frequency
Wave-length	Intensity and Character	Wave-length	Intensity and Character	Wave-length	λ+	1/λ −	
—	—	4764·20	1	—	1·31	5·8	20981·0
—	—	†4574·9	1n	4575·3	1·25	6·0	21852
—	—	† 67·95	1n	68·0	,,	,,	885·4
—	—	† 52·75	3b	52·8	,,	6·1	957·5
†4131·0	4b	—	—	4131·4	1·13	6·8	24200
† 28·2	4b	4128·1	5b	28·3	,,	,,	217
—	—	—	—	16·4	,,	,,	292
—	—	* 08·2	1n	—	,,	,,	364
—	—	4096·8	1b	—	,,	6·9	402
—	—	—	—	4089·1 ?	1·12	,,	447 ?
—	—	30·1	2b	—	1·11	7·0	743
—	—	21·0	1b	—	,,	,,	862
3905·80	3b	*3905·71	5r	—	1·08	7·3	25594·5
—	—	3883·46	1s	—	1·07	,,	739·7
—	—	71·60	1 (CN)	—	,,	,,	819·4
3862·75	3b	62·80	4n	3862·7	,,	7·5	880·7
56·20	3b	56·19	5n	56·1	1·06	,,	924·7
54·00	1b	54·02	1n	—	,,	,,	939·5
—	—	53·62	1n	—	,,	,,	942·1
34·4	1	—	—	—	,,	,,	26072
26·7	1	—	—	—	,,	,,	125
—	—	‡06·90	3n	—	1·05	7·4	260·6
3795·9	2	3796·50	2n	—	,,	,,	332·6
91·1	1	91·8	1b	—	,,	,,	366
—	—	91·0	1n	—	,,	,,	371
3191·1	1	—	—	—	0·90	8·9	31328
—	—	3093·6	1b	—	0·87	9·2	32315·8
3086·8	1	86·6	1b	—	,,	,,	389
2987·77	4	*2987·77	1	—	0·84	9·6	33450·8
2881·70	10	*2881·78	15	—	0·82	10·0	34688·4
2689·8	1	—	—	—	0·77	10·8	37181
77·4	1	—	—	—	,,	10·9	338
59·0	1	—	—	—	,,	,,	597
31·39	8	*2631·38	3	—	0·76	11·0	983·6
2568·8	2	2568·8	1n	—	0·75	11·3	38917
41·89	8	41·90	2	—	0·74	11·5	39330
34·7	1	—	—	—	,,	,,	440·9
33·2	4	32·45	1	—	,,	,,	452·6
28·60	8	* 28·60	8	—	,,	11·6	530
24·21	8	* 24·21	6	—	,,	,,	593·6
19·30	8	* 19·30	5	—	,,	,,	666
16·21	10	* 16·26	10	—	0·73	,,	719·4
14·42	7	* 14·41	5	—	,,	,,	750·8

SILICON (SPARK SPECTRUM)—*continued.*

Eder and Valenta		Exner and Haschek		Lockyer	Reduction to Vacuum		Oscillation Frequency
Wave-length	Intensity and Character	Wave length	Intensity and Character	Wave-length	*λ+	$\frac{1}{\lambda}$−	
2506·99	8	*2507·01	6	—	0·73	11·7	39861·0
2479·8	1	2478·68	1 (CN)	—	"	11·8	40317·6
52·22	3	52 23	1n	—	"	12·0	752·9
46·0	3	45·63	1	—	0·72	"	871·7
—	—	* 43·91	1n	—	"	"	904·7
43·46	2	* 43·47	1n	—	"	"	905·4
38·86	2	* 38·87	1n	—	"	12·1	988·5
35·25	8	35·22	3	—	"	"	41040·1
2356·9	1	—	—	—	0·70	12·6	42416
03·3	1	—	—	—	0·69	13·0	43403
—	—	2296·96	1 (C)	—	"	"	522·1
2219·5	1	—	—	—	0·67	13·7	45041
18·15	1	—	—	—	"	"	053·4
16·76	4	* 16·75	1n	—	"	"	092·8
11 8	3	* 11·87	1n	—	"	13·8	194·4
10·9	3	* 10·97	1	—	"	"	217·3
08·1	3	* 08·1	1	—	"	"	274
2122·8	2	—	—	—	0·65	14·6	47092
1929·0	1	—	—	—	0·62	16·6	51823

ARGON (VACUUM TUBE).

The red end of the red spectrum of Argon.

Runge, 'Astroph. J.,' ix. p. 281. 1899.
Runge and Paschen, 'Astroph. J.,' viii. 99. 1898.

* These lines belong also to the 'blue spectrum.'

Wave-length (Runge)	Intensity	Previous Measurements			Reduction to Vacuum		Oscillation Frequency
		Runge and Paschen	Kayser	Crookes	λ+	$\frac{1}{\lambda}$−	
8014·73	1	—	—	—	2·17	3·4	12473·6
06·00	1	—	—	—	2·16	"	487·2
7948·32	1	7952	—	—	2·15	"	577·9
7724·15	2	7725	7723·4	—	2·09	3·5	942·9
7635·19	3	7636·2	7635·6	7646	2·07	"	13093·7
7514·77	3*	7515·4	7515·1	—	2·04	3·6	303·5
04·04	7	04·5	03·4	7506	2·03	"	322·6
7435·77	1	—	—	—	2·01	"	444·9
7384·18	5*	7384·22	7383·9	7377	2·00	3·7	538·8
72·28	1	—	—	—	—	—	560·6
53·42	1	—	—	—	1·99	—	597·3
16·15	1	—	—	—	1·98	—	664·7
11 80	1	—	—	—	—	—	672·8
7273·13	5*	7273·04	7271·6	7263	1·97	—	745·5
07·20	1	—	—	—	1·95	—	871·3

Nasini, Anderlini, and Salvadori [*Accad. Lincei Atti*, viii. 269 (1899)] give infra-red lines at 7980, 8030, 8140, 8320, 8450, and 8575.

ARGON (VACUUM-TUBE)—*continued.*

† These lines belong only to the 'blue spectrum.'

Wave-length	Intensity and Character	Previous Measurements		Reduction to Vacuum		Oscillation Frequency
Runge and Paschen		Kayser	Crookes	λ+	1/λ−	
7147·30	1	7146·8	—	1·94	3·8	13987·5
7068·83	1	—	—	1·92	,,	14142·8
67·54	5*	7066·6	7056·4	,,	,,	155·4
30·54	2*	29·2	—	1·91	,,	219·9
6965·81	6*	6964·8	6965·6	1·89	3·9	351·9
37·99	2*	37·8	—	1·88	,,	409·5
6888·83	1	—	—	1·87	,,	512·3
80·26	1	—	—	,,	,,	30·4
71·56	4*	6870·6	—	1·86	,,	48·8
27·85	<1	—	—	,,	4·0	641·9
6766·97	1	—	—	1·83	,,	773·7
56·58	1	—	—	,,	,,	96·4
53·15	5*	6752·7	6754	,,	,,	803·9
19·33	2	—	—	1·82	,,	78·4
6699·06	3	—	—	,,	,,	923·5
84·95	<1†	6684·2	—	,,	,,	55·0
82·7	2	—	—	1·81	,,	60
79·01	<1	—	—	,,	,,	68·3
77·61	6*	76·5	6664	,,	,,	71·4
64·27	3	—	—	,,	4·1	15001·3
60·92	3	—	—	,,	,,	08·8
44·3	3†	44·2	—	1·80	,,	46
40·5	1†	—	—	,,	,,	55
38·7	2†	38·6	—	,,	,,	59
32·07	1	—	—	,,	,,	74·1
15·2	<1†	—	—	,,	,,	113
05·05	4	—	—	1·79	,,	35·9
6538·43	3*	—	—	1·78	,,	290·1
13·87	1	—	—	1·77	,,	347·8
6494·10	2	—	—	1·76	4·2	94·4
83·6	3†	6482·8	—	,,	,,	419
81·17	2	—	—	,,	,,	25·1
66·65	3	—	—	,,	,,	59·8
31·77	3*	—	—	1·75	,,	543·6
16·54	3*	15·2	6407	1·74	,,	80·5
02·21	1	—	—	,,	,,	615·4
6384·89	5*	6384·5	6377	,,	,,	57·8
69·74	4	68·0	—	,,	,,	95·0
65·02	3	—	—	1·73	,,	706·7
34·24	<1	—	—	1·72	4·3	82·9
09·36	1	—	—	,,	,,	845·2
07·91	5	07·8	—	,,	,,	48·8
6299·01	<1	—	—	1·71	,,	71·2
97·15	5	6296·8	6302	,,	,,	75·9
78·80	2	—	—	,,	,,	922·3
66·70	1	—	—	1·70	,,	53·1
59·58	<1	—	—	,,	,,	71·2
48·65	4	—	—	,,	,,	99·2
43·45	3†	43·7	—	,,	,,	16012·5
40·5	<1†	—	—	,,	,,	20
38·58	<1	—	—	,,	,,	25·0

ARGON (VACUUM-TUBE.)—*continued.*

Wave-length Runge and Paschen	Intensity and Character	Previous Measurement Kayser	Previous Measurement Crookes	Reduction to Vacuum λ+	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency
6235·99	1	43·7	—	1·70	4·3	16031·6
30·96	2	—	—	1·69	,,	40·6
24·85	1	—	—	,,	,,	60·3
—	—	17·5	—	,,	4·4	79·2
16·14	6	—	—	,,	,,	82·7
—	—	15·6†	—	,,	,,	84·2
12·73	6	12·5	6210	,,	,,	91·6
6199·44	<1	—	—	,,	,,	126·1
97·30	<1	—	—	,,	,,	31·7
94·25	<1	—	—	,,	,,	39·6
89·5	<1†	—	—	1·68	,,	52
86·52	<1	—	—	,,	,,	59·8
83·12	<1	—	—	,,	,,	68·7
79·50	2	—	—	,,	,,	78·1
73·32	6*	6172·9	6173	,,	,,	94·3
72·7	5†	72·3	—	,,	,,	96
70·39	5	70·3	—	,,	,,	202·0
65·30	3	—	—	,,	,,	15·4
61·68	2	—	—	,,	,,	24·9
59·60	1	—	—	,,	,,	30·4
55·46	5	55·2	—	1·67	,,	41·3
45·64	6	45·6	6143	,,	,,	67·3
43·16	1	—	—	,,	,,	73·9
39·1	1†	40·9	—	,,	,,	85
35·63	1	—	—	,,	,,	93·8
34·12	<1	—	—	,,	,,	97·9
29·02	3	—	—	,,	,,	311·4
27·57	4	—	—	,,	,,	15·3
25·96	1	—	—	,,	,,	19·6
23·8	<1†	—	—	,,	,,	25
21·93	2	—	—	,,	,,	30·3
19·74	3	—	—	,,	,,	36·2
15·05	2†	14·1	—	1·66	,,	48·7
13·55	3	—	—	,,	,,	52·7
05·87	6	06·1	—	,,	,,	73·3
04·71	3	—	—	,,	,,	76·4
01·33	3	—	—	,,	,,	85·5
6099·03	6	6098·8	6099	,,	,,	91·6
96·09	1	—	—	,,	,,	99·6
93·44	1	—	—	,,	,,	406·7
90·97	4	—	—	,,	,,	13·3
85·90	1	—	—	,,	4·5	26·9
81·50	2	—	—	,,	,,	38·8
75·20	1	—	—	1·65	,,	55·9
67·48	<1	—	—	,,	,,	77·8
64·93	3	—	—	,,	,,	83·7
59·62	7	59·5	6056	,,	,,	98·2
52·96	6	52·7	—	,,	,,	516·3
43·48	8	43·0‖	6045	,,	,,	42·2
40·46	<1	—	—	1·64	,,	50·5
35·49	<1	—	—	,,	,,	64·2
32·39	9	31·5‖	6038	,,	,,	72·7

‖ 6043·68, 6032·69, Eder and Valenta.

ARGON (VACUUM-TUBE)—*continued.*

Wave-length Runge and Paschen	Intensity and Character	Previous Measurement Kayser	Previous Measurement Crookes	Reduction to Vacuum λ+	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency
6025·40	4	6025·8	—	1·64	4·5	16591·9
17·66	1	—	—	,,	,,	613·3
15·40	<1	—	—	,,	,,	19·5
13·94	4	13·6	—	,,	,,	23·5
11·59	1	—	—	,,	,,	30·0
05·95	3	—	—	,,	,,	45·7
5999·29	4	5999·5	—	1·63	,,	64·2
94·99	2	—	—	,,	,,	76·1
87·61	5	87·5	—	,,	,,	91·7
82·22	2	—	—	,,	,,	716·7
71·91	4	—	—	,,	,,	40·6
68·58	3	—	—	,,	,,	49·9
64·70	3	—	—	1·62	,,	60·8
60·78	<1	—	—	,,	4·6	71·8
49·47	3	—	—	,,	,,	803·7
42·92	5	43·5	—	,,	,,	22·1
41·08	3	—	—	,,	,,	27·3
29·06	6	28·5‖	5926	1·61	,,	61·5
27·34	3	—	—	,,	,,	66·4
30·33	<1	—	—	,,	,,	86·3
20·04	<1	—	—	,,	,,	87·1
16·84	3	—	—	,,	,,	96·3
12·31	7	12·22 ‖	5909	,,	,,	909·3
04·09	<1	—	—	,,	,,	32·8
00·70	<1	—	—	,,	,,	42·5
5897·75	<1	—	—	,,	,,	51·0
88·79	6	5888·93 ‖	5887	1·60	,,	76·8
82·88	4	82·78 ‖	—	,,	,,	93·9
80·41	<1	—	—	,,	,,	17001·0
70·52	1	—	—	,,	,,	29·7
64·29	<1	—	—	,,	,,	47·8
60·54	4	60·61 ‖	5858	,,	,,	58·7

‖ 5928·61, 5912·48, 5889·02, 5883·03, 5860·69, Eder and Valenta.

VANADIUM.

Hasselberg: 'Kongl. Svenska Vetenskaps-Akadem. Handl.,' Bd. xxxii., No. 2. 1899
Rowland and Harrison: 'Astrophys. Jour.' April 1898.
Exner and Haschek: 'Sitzber. kais. Akad. Wissensch. Wien,' Bd. cvii. (2). 1898
Lockyer and Baxandall: 'Proc. Roy. Soc.,' vol. lxviii. p. 189. 1901.

† Coincident with Fraunhofer lines.

Arc Spectrum Hasselberg	Arc Spectrum Rowland and Harrison	Intensity and Character	Reduction to Vacuum λ+	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
5850·60	—	2	1·59	4·6	17087·7
46·56	—	4n	,,	,,	099·5
39·34	—	2	,,	4·7	120·5
30·97	—	4n	,,	,,	145·1

VANADIUM—*continued.*

Arc Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison		λ+	1/λ −	
5817·80	—	3	1·59	4·7	17183·9
17·33	—	3	,,	,,	185·3
07·40	—	4	1·58	,,	214·7
00·17	—	3	,,	,,	236·2
5788·85	—	3	,,	,,	269·9
86·42	5786·413	4	,,	,,	277·2
84·64	84·646	4	,,	,,	282·5
83·76	83·764	2	,,	,,	285·1
83·14	—	2	,,	,,	286·9
82·85	82·848	2	,,	,,	287·8
76·95	76·930	4n	1·57	,,	305·5
72·66	72·657	4s	,,	,,	318·3
61·70	61·674	3	,,	,,	351·3
52·99	52·985	3	,,	,,	377·6
50·90	—	3	,,	,,	383·9
49·13	—	4s	,,	,,	389·2
47·98	—	2s	,,	,,	392·7
43·67	43·675	5	,,	,,	405·8
37·28	37·310	6	1·56	,,	425·1
34·26	34·254	4	,,	,,	434·3
33·63	—	2	,,	,,	435·3
33·34	33·336	3	,,	,,	437·1
31·48	—	7	,,	,,	442·8
27·90	27·900	5	,,	,,	453·7
27·25	27·289†	8	,,	,,	455·6
25·90	25·881	4s	,,	,,	459·8
16·49	16·461	3	,,	4·8	488·5
09·25	09·198	3	,,	,,	510·7
07·26	07·236†	7	,,	,,	516·8
03·83	03·825†	7	1·55	,,	527·3
5698·74	5698·765	8	,,	,,	542·9
88·02	87·993	2	,,	,,	576·0
83·47	83·451	3	,,	,,	590·1
71·10	71·091	7	,,	,,	628·5
68·61	68·608	5	,,	,,	636·2
57·67	57·689	5	,,	,,	670·3
57·11	57·119	2	1·54	,,	672·1
46·36	46·352	5	,,	,,	705·7
35·76	35·742	3	,,	,,	739·1
—	34·145	2	,,	,,	744·1
32·73	32·702	2	,,	,,	748·6
27·86	27·886†	7	1·53	,,	763·9
26·27	26·267	5	,,	,,	769·0
25·16	25·121	4	,,	,,	772·5
24·80	24·853	5	,,	,,	773·5
—	24·446	2	,,	,,	774·7
22·34	22·319	3	,,	,,	781·4
05·20	05·187	5	,,	4·9	835·7
04·91	04·875	2	,,	,,	836·7
04·44	04·443	5	,,	,,	838·1
01·63	01·627	2	,,	,,	847·0
—	5598·047	2	,,	,,	858·5
—	94·731	2	,,	,,	869·1
5593·22	93·208	3	,,	,,	873·9
92·67	92·670	6	,,	,,	875·6

VANADIUM—*continued.*

Arc Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison		$\lambda +$	$\frac{1}{\lambda} -$	
5588·71	5588·713	3	1·52	4·9	17888·3
86·26	86·232	4	„	„	896·2
85·00	84·979†	3 ? V	„	„	900·2
84·75	84·745	5	„	„	901·0
—	84·602	4	„	„	901·5
—	76·752	4	„	„	926·7
—	67·702	4	„	„	955·8
—	66·156	4	„	„	960·8
61·92	61·897	4	„	„	974·5
59·00	58·995	4	„	„	983·9
57·71	—	2	„	„	988·1
48·41	48·401	2	1·51	„	18018·3
47·31	47·306	5	„	„	021·9
46·18	46·165	4	„	„	025·6
—	45·101	4	„	„	029·0
—	42·954	4	„	„	036·0
—	35·659	4	„	„	059·8
—	35·082	4	„	„	061·7
—	34·056	4	„	„	065·0
—	17·437	4	„	„	119·4
—	15·301	4	„	„	126·5
11·41	11·413	3	1·50	„	139·3
—	08·865	4	„	„	147·6
07·97	07·744	5	„	„	151·0
—	06·097	4	„	„	156·8
05·13	05·097	3	„	„	160·0
5490·22	5490·181	3	„	5·0	209·3
88·18	88·312	4	„	„	215·7
87·48	87·455	3	„	„	218·3
71·56	71·563	2	1·49	„	271·3
68·05	68·032	2	„	„	283·1
64·30	—	2	„	„	295·6
58·39	—	4	„	„	315·4
—	55·031‡	4	„	„	326·7
43·50	43·466	2	„	„	365·6
37·93	37·885	3	1·48	„	384·4
34·43	34·410	4	„	„	396·2
—	24·281‡	2	„	„	430·6
21·96	—	2	„	„	438·5
20·32	—	2	„	„	444·1
18·33	18·318	5	„	„	450·9
15·51	15·479‡	5	„	„	460·5
02·17	02·148	5	„	„	506·1
5398·13	—	3	1·47	5·1	519·8
88·56	5388·534†	3	„	„	552·8
85·39	—	4	„	„	563·7
83·68	83·651	4	„	„	569·6
—	53·619	4	1·46	„	673·8
—	38·812	2	„	„	725·7
30·65	30·616	2	„	„	754·4
29·05	—	2	„	„	760·0
02·40	—	2	1·45	5·2	854·2
5287·88	—	2	1·44	„	906·0

‡ 5455·02 Ruthenium. ‡ 5424·274, 5415·43 iron.

VANADIUM—*continued.*

Arc Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison		$\lambda+$	$\frac{1}{\lambda}-$	
5282·75	—	2	1·44	5·2	18924·3
72·92	—	2	,,	,,	959·7
71·28	5271·119	2	,,	,,	965·8
66·33	—	2	,,	,,	983·4
61·20	61·149	2	,,	,,	19002·0
60·56	60·527	2	,,	,,	004·3
—	58·308	2	,,	,,	012·3
41·06	41·055	4s	1·43	,,	074·9
40·40	40·364	2	,,	,,	077·4
34·31	34·249	4s	,,	,,	099·6
33·91	33·895	2	,,	,,	101·0
25·97	25·920	3	,,	,,	131·7
16·80	16·772	3	,,	,,	163·7
13·87	13·837	2	,,	,,	174·5
12·47	12·399	2	1·42	,,	179·7
07·89	07·844	2	,,	5·3	196·4
06·82	06·790	2	,,	,,	200·3
—	00·520	4	,,	,,	223·5
—	5197·215	4	,,	,,	235·8
5195·58	95·564†	4	,,	,,	241·9
95·01	95·021	4	,,	,,	243·9
93·82	93·795	4	,,	,,	248·3
93·18	93·184† ? V	4	,,	,,	250·7
92·22	92·193	2	,,	,,	254·3
83·07	83·033	2	,,	,,	288·4
81·01	80·926	2	,,	,,	296·1
79·35	79·275	2	,,	,,	302·2
78·75	78·733	2	,,	,,	304·4
77·03	76·956	4	,,	,,	310·9
—	76·683	2	,,	,,	312·1
—	74·714	2	1·41	,,	319·4
72·35	72·284	2	,,	,,	328·4
70·15	70·114	2	,,	,,	336·6
—	69·126	2	,,	,,	340·3
67·04	66·961	2	,,	,,	348·3
65·14	65·072	2	,,	,,	355·3
59·56	59·520	4	,,	,,	376·3
—	59·438	2	,,	,,	376·6
57·27	—	2	,,	,,	384·8
48·95	48·893	4	,,	,,	416·3
39·74	39·704	4	,,	,,	451·0
38·58	38·597	4	,,	,,	455·3
—	37·772	2	1·40	,,	458·4
28·71	28·705	5	,,	,,	492·8
05·37	05·324	3	,,	5·4	581·9
5064·32	5064·296	3	1·39	,,	740·6
60·91	60·831	2	1·38	,,	754·0
—	51·781	2	,,	,,	789·6
—	47·484	2	,,	,,	806·5
14·83	14·811		1·37	5·5	935·4
02·54	02·505	4	,,	,,	984·4
4943·04	—	3	1·35	5·6	20224·9
33·82	4933·786	2	,,	,,	262·8

VANADIUM—*continued.*

Arc Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison		$\lambda +$	$\frac{1}{\lambda} -$	
*4932·24	4932·212†	4	1·35	5·6	20269·2
* 25·83	25·837	5	,,	,,	295·9
* 22·60	22·543	3	,,	,,	309·0
—	19·171	2	,,	,,	323·0
* 6·48	16·436	3	1·34	,,	334·2
—	13·277	2	,,	,,	347·4
08·92	08·882	2	,,	,,	365·6
—	07·046	2	,,	,,	373·2
* 06·06	—	2	,,	,,	376·4
* 05·10	05·050	3	,,	,,	381·3
* 04·59	04·575†	6	,,	,,	383·5
* 00·84	00·820	5	,,	,,	399·1
*4894·43	4894·396	4	,,	,,	425·9
* 91·81	91·767	4	,,	,,	436·8
* 91·43	91·414	3	,,	,,	438·4
* 90·32	90·265	3	,,	,,	443·1
* 87·02	86·990	4	,,	,,	456·8
* 85·36	85·327	4	,,	,,	461·7
—	*82·359	4	,,	,,	476·3
* 81·75	81·745†	5	,,	,,	478·9
* 80·77	80·746	5	,,	,,	483·0
* 75·66	75·674†	8	1·33	,,	504·4
—	73·170	2	,,	,,	514·9
* 71·46	71·453	4	,,	,,	522·1
—	70·334	2	,,	,,	526·9
* 64·93	64·943	8	,,	,,	549·7
* 62·83	62·801†	4	,,	,,	558·6
* 59·34†	—	4	,,	5·7	573·2
—	*58·809	4	,,	,,	575·5
—	*57·241	2	,,	,,	582·1
—	54·114	2	,,	,,	595·3
—	52·155	2	,,	,,	603·7
* 51·65	51·686†	8	,,	,,	605·8
—	49·458	2	,,	,,	615·2
—	49·262	2	,,	,,	616·0
* 48·98	49·004	3	,,	,,	617·1
—	*46·799	2	,,	,,	626·5
* 43·16	43·195	3	,,	,,	641·9
—	35·040	2	1·32	,,	676·6
—	34·264	2	,,	,,	679·9
—	*34·005	2	,,	,,	681·1
* 33·17	33·213	4	,,	,,	684·5
* 32·59	32·617†	6	,,	,,	687·1
* 31·80	31·836†	7	,,	,,	690·4
* 30·86	30·879	3	,,	,,	694·5
—	29·427	2	,,	,,	700·7
* 29·00	29·008	3	,,	,,	702·5
* 27·62	27·638†	7	,,	,,	708·4
—	23·031	2	,,	,,	728·1

* Observed also by Lockyer and Baxandall, whose numbers are: 4932·23, 25·87, 22·60, 16·46, 08·90, 06·05, 05·05, 04·60, 00·82, 4894·42, 94·74, 91·40, 90·30, 87·03, 85·39, 82·36, 81·75, 4880·82, 75·71, 71·50, 64·92, 62·83, 59·38, 58·80, 57·20, 51·69, 49·05, 46·80, 43·20, 34·00, 33·24, 32·61, 31·85, 30·90, 29·00, 27·63.

VANADIUM—*continued.*

Arc Spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison		λ+	1/λ −	
*4819·22	4819·225	3	1·32	5·7	20744·5
—	*08·842	2	,,	,,	789·3
* 07·70	07·736†	7	,,	,,	794·2
—	*03·240	2	1·31	,,	813·6
—	02·373	2	,,	,,	817·3
*4799·94	4799·972†	4	,,	,,	827·8
* 99·20	99·210	3	,,	,,	831·0
* 98·12	98·151	3	,,	,,	835·7
* 97·07	97·119†	6	,,	,,	840·2
* 95·27	95·293	4	,,	,,	848·1
—	94·730	2	,,	,,	850·5
* 93·10	93·135	4	,,	,,	857·6
—	89·103	2	,,	,,	875·0
* 86·70	86·706†	6	,,	,,	885·5
* 84·65	84·663	4	,,	,,	894·4
—	81·514	2	,,	5·8	908·2
* 76·70†	76·644	4	,,	,,	929·3
* 76·54†	—	6	,,	,,	929·8
* 73·25	73·263	3	,,	,,	944·2
* 72·74	72·781	2	,,	,,	946·4
—	69·208	2	,,	,,	962·0
* 66·80	66·838†	5	1·30	,,	971·6
* 65·84	65·859	3	,,	,,	976·8
—	*64·224	2	,,	,,	984·0
—	*59·210	2	,,	,,	21006·1
* 57·68	57·686	5	,,	,,	012·8
* 57·55	—	4	,,	,,	013·4
* 54·13	—	5	,,	,,	028·5
—	*52·036	2	,,	,,	037·8
* 51·75	51·759	4	,,	,,	039·1
* 51·45	51·463	2	,,	,,	040·4
* 51·16	51·211	4	,,	,,	041·6
* 48·70	48·723	4	,,	,,	052·5
* 47·30	47·313	3	,,	,,	058·8
* 46·81	46·827	4	,,	,,	060·9
* 42·79	42·819	4	,,	,,	078·8
* 39·79	39·849	2	,,	,,	092·1

* Lockyer and Baxandall, 4819·23, 08·84, 07·73, 03·24, 4799·98, 99·20, 98·19, 97·08, 95·35, 93·15, 86·71, 84·72, 76·63, 73·29, 72·76, 66·82, 65·91, 64 22, 59·20, 58·95, 57·62, 54·13, 52·05, 51·79, 51·45, 51·18, 48·70, 47·30, 46·87, 42·86, 39·80.

VANADIUM—*continued.*

'' Signifies that the line is double; b^v that the line is sharply defined on the violet side and nebulous towards the red; and b^r means that it is sharp on the less refracted side and nebulous towards the violet.

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	λ+	$\frac{1}{\lambda}$−	
* 4738·51	4738·505		3		1·30	5·8	21097·9
* 37·91	37·924		2		,,	,,	100·5
* 32·12	32·108		3		,,	,,	126·4
* 31·74	31·745		3		,,	,,	128·1
* 31·42	31·443		3		,,	,,	129·5
* 30·57	30·574		4		,,	,,	133·3
* 29·73	29·724		4		1·29	,,	137·1
* 28·85	28·840		2		,,	,,	141·0
	* 24·075		2		,,	,,	162·3
* 23·65	23·626		2		,,	,,	164·3
* 23·06	23·055		5		,,	,,	166·9
* 21·70	21·704		5		,,	,,	173·0
* 21·42	21·444		3		,,	,,	174·2
* 17·85	17·874		5		,,	,,	190·3
* 16·36	16·377		3		,,	,,	197·0
* 16·08	16·079		4		,,	,,	198·3
* 15·61	15·650		3		,,	,,	200·3
	* 15·488 Ti		2		,,	,,	200·9
* 14·28†			5		,,	,,	206·4
* 13·61	13·639		3		,,	,,	209·3
* 10·74	10·746		5		,,	,,	222·3
	09·130		2		,,	,,	229·5
	08·397		2		,,	,,	232·8
* 07·62†	07·629		4		,,	5·9	236·3
* 06·75†	06·761		5		,,	,,	240·2
* 06·34	06·357		5		,,	,,	242·0
* 05·26	06·278		4		,,	,,	246·8
	* 02·689		2		,,	,,	258·5
4699·52†	4699·505		4		,,	,,	272·9
* 90·45	90·438		2		1·28	,,	314·0
* 88·24			2		,,	,,	324·1
* 87·10	87·100		5		,,	,,	329·3
* 84·64	84·634		4		,,	,,	340·5
†82·09 ? V			2		,,	,,	352·1
* 81·07†	81·073		3		,,	,,	356·7
* 79·95	79·961		3		,,	,,	361·8
* 79·65			2		,,	,,	363·2
* 73·83	73·836		2		,,	,,	389·8
* 72·48†?V			2		,,	,,	396·0
* 70·66	70·666	4670·65	8	8	,,	,,	404·3
* 69·50†	69·487		2	—	,,	,,	409·7
* 66·33†		66·32	4	2	,,	,,	424·2
	63·314 } * 62·605 }	63·07	6	2	,,	,,	439·2
62·02			2		,,	,,	444·0
* 61·01			2		,,	,,	448·7
* 57·17†	57·138	57·15	2	2n	,,	,,	466·5

* Lockyer and Baxandall, 4738·60, 37·90, 32·17, 31·80, 31·40, 30·58, 29·77, 28·85, 24·07, 23·65, 23·06, 21·71, 21·40, 17·89, 16·39, 16 11, 15·62, 15·50, 14·29, 13·65, 10·75, 07·64, 06·76, 06·38, 05·23, 02·70, 4690·45, 88·24, 87·11, 84·57, 81·12, 80·03, 79·68, 73·83, 72·48, 70·66, 69·50, 66·34, 62·60, 62·00, 61·00, 57·17, also lines at 4709·93 and 4682·93.

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and *Haschek	Arc	Spark	λ+	$\frac{1}{\lambda}-$	
		4656·65		2n	1·28	5·9	21468·8
*4655·47	4655·410	55·43	2	2	,,	,,	474·3
* 54·84			3		1·27	,,	477·1
* 53·15	53·106	53·15	2	2n	,,	,,	485·0
* 49·08†	49·068	49·05	3	2	,,	,,	503·8
* 48·08	48·046		2		,,	,,	508·4
* 46·59	46·571	46·58	5	6	,,	,,	515·7
* 46·17	46·156		2		,,	,,	517·2
* 44·64	44·624	44·67	4	2	,,	,,	524·3
	* 44·239	44·25		2	,,	,,	526·1
* 40·92	40·916	40·91	4	4	,,	,,	541·6
* 40·25	40·232	40·23	4	4	,,	,,	544·7
36·34	36·343	26·33	3	2	,,	,,	562·8
35·35	35·346	35·34	5	4	,,	,,	567·5
		34·4		2	,,	6·0	572
30·24	30·236		2		,,	,,	591·2
26·67†	26·666	26·67	4	4	,,	,,	607·9
24·62	24·581	24·60	4	4	,,	,,	617·5
21·43	21·426		2		,,	,,	632·3
19·97 }	19·896	19·93	5	10	,,	,,	639·3
19·85 }			4		,,	,,	639·7
		*19·0		2n	,,	,,	644
		18·7		2n	,,	,,	645
* 18·00		18·03	2	2	,,	,,	648·3
		17·48		2	1·26	,,	650·8
* 17·03		17·02	2	2	,,	,,	653·0
* 16·18	16·190	16·20	2	2	,,	,,	656·9
* 14·08†?V	14·094		2		,,	,,	666·8
	13·076				,,	,,	667·3
* 11·92		11·94	4	2	,,	,,	676·9
* 11·10	11·103	11·13	3	2	,,	,,	680·7
* 09·84	09·821	09·82	4	4	,,	,,	686·8
	08·635				,,	,,	692·4
* 07·40	07·390	07·47	3	2	,,	,,	698·2
* 06·33	06·321	06·34	5	6	,,	,,	701·2
		05·53		2	,,	,,	707·0
* 00·34		00·40	3	10b^r	,,	,,	731·4
*4594·27†	4594·216	4594·31	9	12	,,	,,	760·2
* 91·39	91·406	91·41	5	8	,,	,,	773·3
		90·63		2	,,	,,	777·5
		89·05		2	,,	,,	785·0
* 88·94		88·88	2	2	,,	,,	785·7
* 86·54†	86·554	86·55	9	12	,,	,,	796·9
* 86·15		86·10	3	2	,,	,,	798·9
* 83·96	83·967	83·41	4	4	,,	,,	809·2
	* 81·409	81·36		2	,,	,,	821·5
* 80·57†	80·562	80·60	8	10b^r	1·25	,,	825·3
* 79·38	79·373	79·32	5	4	,,	,,	831·1
* 78·92	78·908	78·90	6	6	,,	,,	833·3
* 77·36†	77·348	77·38	8	10	,,	,,	840·7
* 71·96	71·959	72·00	6	10b^r	,,	,,	866·4

* Lockyer and Baxandall, 4655·50, 54·80, 53·13, 49·07, 48·08, 46·52, 46·20, 44·66, 44·24, 40·92, 40·27, 36·36, 35·38, 30·25, 26·66, 24·61, 21·42, 19·92, 19·00, 18·00, 17·00, 16·20, 14·10, 11·95, 11·11, 09·84, 07·42, 06·33, 00·41, 4594·27, 91·41, 88·97, 86·51, 86·20, 83·96, 81·40, 80·57, 79·38, 78·89, 77·33, 71·97.

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	λ+	$\frac{1}{\lambda}$−	
* 4570·60		4570·57	4	4	1·25	6·0	21873·0
		69·4		2	,,	,,	879
		67·40		2	,,	,,	888·3
* 64·76	4564·756	64·80	2	12	,,	,,	900·9
		63·35		2	,,	6·1	904·7
		63·55		2	,,	,,	906·7
* 60·90	60·893	60·90	6	12	,,	,,	919·4
		58·60		2n	,,	,,	930·5
		56·95		2n	,,	,,	938·6
		55·53		2	,,	,,	945·2
* 53·25		53·22	5	8b	,,	,,	956·3
	52·735	52·67		2	,,	,,	958·9
* 52·05	52·016	51·99	4	2	,,	,,	962·1
* 49·81†	49·824	49·85	6	12	,,	,,	972·8
		47·97		2	,,	,,	981·8
* 45·57	45·566	45·60	7	14	,,	,,	993·3
* 41·57		41·5	2	2b	1·24	,,	22012·9
* 40·18	40·179	40·18	4	4	,,	,,	019·5
* 37·84†	37·834	37·80	4	4	,,	,,	020·9
		36·1	6	2b	,,	,,	039·3
		35·73		2	,,	,,	041·1
		35·4		2n	,,	,,	042·7
		34·94		2	,,	,,	044·9
	* 34·107	34·11	6	4	,,	,,	049·0
* 30·97	30·972	30·95	4	2	,,	,,	064·3
* 29·76		29·73	5	4	,,	,,	070·2
* 29·47	29·476	29·45	4	2	,,	,,	071·6
* 28·66		28·69	4	8	,,	,,	075·4
* 28·16	28·168	28·12	5	4	,,	,,	078·0
* 25·31†	25·337	25·31	4s also Fe	4	,,	,,	091·7
* 24·38	24·378	24·41	6	6	,,	,,	096·3
		23·97		2n	,,	,,	098·4
		22·32		2	,,	,,	106·5
		20·70		2	,,	,,	*114·4
* 20·67	20·685	20·63	3n	2	,,	,,	114·7
* 20·31	20·331	20·32	4n	2″	,,	,,	116·2
* 17·77†	17·738	17·70	4	4	,,	,,	128·9
		16·85		2n	,,	,,	133·2
		16·21		2n	,,	,,	136·3
* 15·74	15·729	15·71	3	2	,,	,,	138·7
* 14·36†	14·357	14·37	5 also Fe,Co	4	,,	,,	145·4
13·79	13·792	13·78	4	2	,,	,,	148·2
		12·92		6n	,,	,,	152·5
* 11·64	11·605	11·60	4	2	,,	,,	158·9
* 09·49†	09·463	09·46	4	2	,,	,,	169·5
		08·44		2n	,,	,,	174·5
* 08·11		08·05	2	2	,,	,,	176·4
* 06·77†	06·744	06·75	4	2	,,	,,	182·9

* Lockyer and Baxandall, 4570·62, 64·79, 60·89, 53·25, 52·03, 49·79, 45·56, 41·6[illegible] 20·3[illegible] 40·18, 37·83, 34·08, 30·98, 29·78, 29·50, 28·64, 28·19, 4525·33, 24·39, 20·71, 17·75, 15·73, 14·36, 13·83, 11·68, 09·46, 08·10, 06·73, 06·40, also lines at 4603·1[illegible] 4555·59.

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	$\lambda+$	$\frac{1}{\lambda}-$	
* 4506·41		4506·40	3	2	1·24	6·0	22184·6
* 06·30		06·27	4	2	,,	,,	185·0
* 02·12	4502·121	02·19	6	6b^{r}	1·23	,,	205·6
		* 01·44		2	,,	,,	209·0
* 01·01	01·001	01·00	4n	2	,,	,,	211·2
		4499·97		2	,,	,,	216·3
		98·28		2	,,	,,	224·6
		97·88		2	,,	,,	226·6
* 4497·57	4497·574	97·57	4	4	,,	6·2	228·0
* 97·03†		97·03	4	4	,,	,,	230·7
* 96·26	96·233	96·80	6	6b^{r}	,,	,,	234·6
95·16		95·18	3	2n	,,	,,	239·8
		92·47		2	,,	,,	253·3
91·66	91·648	91·66	2	2	,,	,,	257·3
91·35	91·343	91·35	3s	2	,,	,,	258·8
90·95†	90·981	90·99	5s	4	,,	,,	260·7
		90·3		2n	,,	,,	264·0
89·06†	89·096	89·11	7	10b^{r}	,,	,,	270·0
		88·46		2	,,	,,	273·1
6·44		86·43	2	2	,,	,,	283·2
		85·9		2n	,,	,,	285·9
		83·76	5s	2n	,,	,,	296·5
80·20	80·206	80·26		4b^{r}	,,	,,	313·9
		* 77·46		2	,,	,,	327·9
		76·06	4	2	,,	,,	334·9
76·06		75·85		2	,,	,,	335·9
74·89	74·899	74·93	7	10	,,	,,	340·7
74·21	74·207	74·28	6	10	,,	,,	344·1
		* 73·43		2	,,	,,	348·0
		72·53		2	,,	,,	352·5
		* 71·94		2	,,	,,	355·5
		* 71·50		2	,,	,,	357·7
	70·827 {	71·00 }	2	2	,,	,,	360·2
		70·60 }		2n	,,	,,	362·2
* 69·88	69·871	69·92	7	12b^{r}	,,	,,	365·8
* 68·94	68·931	68·94	4	4	1·22	,,	370·5
* 68·19	68·174	68·20	5	6b^{r}	,,	,,	374·2
		* 67·78		2	,,	,,	376·3
* 67·04		67·05	4	2	,,	,,	379·9
	* 65·675	65·67	6	4	,,	,,	386·8
		* 64·95		4	,,	,,	390·5
		* 64·49		6b^{r}	,,	,,	392·8
		63·80		2	,,	,,	398·7
* 62·56	62·533	62·60	7 see Ni	14	,,	,,	402·3
	60·849	61·20	8	4b^{r}	,,	,,	411·1
* 60·46†	* 60·462	60·52	9	12b^{r}	,,	,,	413·0
* 59·93†	59·918	59·98	8	14	,,	,,	415·6
	* 58·915		2		,,	,,	420·8
		* 58·57	2	2	,,	,,	422·5
* 57·97†		57·98	5	6b^{r}	,,	,,	425·5

* Lockver and Baxandall, 4506·30, 02·12, 01·45, 01·00, 4497·55, 97·00, 96·24, 95·17, 91·65, 91·36, 90·99, 89·08, 86·39, 80·21, 77·48, 74·91, 74·22, 73·45, 71·96, 71·51, 69·87, 68·95, 68·23, 67·87, 67·09, 65·69, 64·95, 64·46, 62·52, 60·52, 59·96 58·57, 58·00, and also 4484·24, 61·18.

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	λ+	$\frac{1}{\lambda}$ −	
* 4457·65†	4457·632	4457·65	7	6	1·22	6·2	22427·1
* 56·68	56·668	56·72	4	4n	,,	,,	432·0
	56·073	56·07 Ca	2	2	,,	,,	435·1
		55·52		2	,,	,,	437·9
	54·939	54·96 Ca	2	4	,,	,,	440·7
		54·32		2	,,	,,	443·9
		53·53		4	,,	,,	447·9
		* 53·37		2n	,,	,,	448·7
* 52·91		52·90	4	4	,,	,,	451·1
* 52·19	52·180	52·23	8	14	,,	,,	454·6
* 51·09†	51·070	51·11	4	6b^{v}	,,	,,	460·[illegible]
* 49·77	49·741	49·76	5	4	,,	,,	466·9
		* 45·99		2	,,	,,	486·0
* 44·40†	44·380	44·42	7 also Ti	10	,,	,,	494·[illegible]
* 43·52	43·508	43·50	4	8	,,	,,	498·[illegible]
		42·53		2	,,	,,	503·5
* 41·88†	41·847	41·90	7 also Ti	14	,,	,,	506·7
		40·65		2n	,,	,,	513·0
		* 39·16		2	,,	,,	520·6
* 38·02†	38·004	38·08	7	12b^{v}	,,	,,	526·2
		37·50		2	,,	,,	529·0
		37·00		2	,,	,,	531·6
* 36·31†	36·309	36·34	7	10	,,	,,	535·2
		35·84		2	,,	,,	537·4
		* 35·53		2	,,	,,	539·0
		35·0		2b	,,	,,	541·7
* 34·80		34·74	4	4	,,	,,	542·9
		* 33·07		2	,,	6·3	551·5
* 30·68		30·72	4	4	1·21	,,	563·5
* 29·95		29·99	6	8b	,,	,,	567·2
* 28·68†	28·676	28·71	6	8	,,	,,	573·7
		* 27·50		8	,,	,,	579·8
* 26·17†		26·23	6	8	,,	,,	586·4
* 25·86†		25·88	4	4	,,	,,	588·1
	25·594 Ca	25·60	2	2	,,	,,	589·5
* 24·74†	24·743	24·75	3	4	,,	,,	594·9
* 24·10	24·082	24·11	3	4	,,	,,	597·2
* 23·41	23·375	23·40	3	6	,,		600·7
23·22			3				601·7
* 22·40†		22·43	3	2	,,	,,	605·8
* 21·73†	21 739	21·82	6	8	,,	,,	609·1
* 20·08		20·19	5	4b^{v}	,,	,,	617·4
		16·9		4n	,,	,,	634·0
* 16·63†	16·626	16·63	6	4	,,	,,	635·4
		** 14·74		2	,,	,,	645·1
		* 13·87		2	,,	,,	649·6
* 12·30	12·299	12·38	4s	4b^{v}	,,	,,	657·4
		11·83		2	,,	,,	660·0
* 08·67†	08·655	08·68	9	14rb^{v}	,,	,,	676·3

* Lockyer and Baxandall, 4457·67, 56·68, 54·34, 53·30, 52·91, 52·19, 51·13, 49·78, 46·04, 44·39, 43·56, 41·90, 39·19, 38·02, 36·33, 35·60, 34·80, 33·09, 30·71, 30·02, 28·72, 27·49, 26·22, 25·95, 24·77, 24·11, 23·40, 22·42, 21·77, 20·14, 16·71, 14·74, 12·33, 08·67.

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	λ+	$\frac{1}{\lambda}$ −	
* 4408·36†	4408·368	4408·40	8	10	1·21	6·3	22677·8
* 07·85†	07·801	07·89	9	12	,,	,,	680·5
* 06·80†	06·805	06·90	9	12	,,	,,	685·8
	* 06·277	06·35	8	6	,,	,,	688·4
* 05·20†		05·19	5s	4	,,	,,	694·2
		04·45		2	,,	,,	698·0
* 03·86	03·831	03·83	3	4	,,	,,	701·2
		01·95		2	,,	,,	710·9
* 00·74†	00·738	00·80	8	18	,,	,,	717·1
		*4399·60		2	,,	,,	723·0
		98·70		2n	,,	,,	727·7
		* 98·05		2	,,	,,	731·0
	4397·392	97·55	2	2	,,	,,	734·0
		* 97·00		2n	,,	,,	736·5
* 4395·40†	95·382	95·49	9	20	,,	,,	744·6
* 94·98†		94·99	3	4	,,	,,	746·9
* 94·01†	94·000	94·03	4	4	,,	,,	751·9
* 93·26	93·258	93·30	4	4	1·20	,,	755·8
* 92·24†	92·234	92·27	4	4	,,	,,	761·1
* 91·84		91·86	3	2	,,	,,	763·2
* 90·79		90·81	2	2	,,	,,	768·6
* 90·13†	90·142	90·23	9r	30	,,	,,	771·9
		89·27		2	,,	,,	776·5
* 87·40		87·37	3	4	,,	,,	786·3
* 84·87†	84·875	84·88	9	40r	,,	,,	799·4
* 84·37		84·35	2	2	,,	,,	802·0
* 84·07			2		,,	,,	803·3
		82·96		2	,,	,,	809·3
		* 81·94		2	,,	,,	814·6
	* 81·187	81·20	2	2n	,,	,,	818·5
* 80·69	80·719	80·72	4	4	,,	,,	821·1
* 79·38†	79·392	79·40	9r	40r	,,	,,	827·9
* 78·06		78·02	4n	2	,,	,,	835·0
		* 76·9		2b	,,	,,	840·9
* 76·25		76·19	2	2	,,	,,	844·5
* 75·47†		75·47	4	4	,,	,,	848·4
		* 75·21		2	,,	,,	849·7
* 73·99†	73·984	73·99	4	4	,,	,,	856·1
* 73·40†	73·383	73·42	4	6b^v	,,	,,	859·2
		70·45		2n	,,	,,	874·6
* 69·25		69·22	2	2	,,	,,	881·1
* 68·76†	68·756	68·73	3	4	,,	,,	883·6
* 68·25†		68·19	4	6	,,	6·4	886·2
		67·74		2	,,	,,	888·7
* 67·24		67·07	2	4n	,,	,,	891·8
* 65·92		65·89	3	2	,,	,,	898·4
* 64·37†	64·377	64·36	4	4b^v	,,	,,	906·4
* 63·69	63·690	63·69	4	4	,,	,,	910·0
* 63·48†		63·49	2	2	,,	,,	911·1

* Lockyer and Baxandall, 4408·35, 07·83, 06·80, 06·33, 05·20, 03·87, 00·74, 4399·63, 98·09, 96·93, 95·42, 95·05, 94·03, 93·28, 92·28, 91·88, 90·80, 90·13, 87·42, 84·92, 84·42, 84·13, 81·93, 81·21, 80·75, 79·44, 78·13, 77·05, 76·25, 75·51, 75·28, 74·01, 73·40, 69·24, 68·78, 68·23, 67·26, 65·94, 64·40, 63·75, 63·54, also 4482·28, 31·91, 31·36, 22·71, 18·88, 17·83, 15·25, 13·90 13·60, 02·79, 01·91, 01·34, 4397·56, 96·61, 95·77.

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	λ+	1/λ −	
* 4361·57		4361·55	3	4	1·20	6·4	22921·2
* 61·18		61·17	2	2	,,	,,	923·2
* 60·75		60·76	3	4	,,	,,	925·4
		60·30		2	,,	,,	927·8
* 57·82		57·75	2	2n	,,	,,	941·0
* 57·60		57·61	3	2	,,	,,	942·0
		* 56·97		2	1·19	,,	945·3
* 56·10†	4356·104	56·16	5	4b^v	,,	,,	949·8
* 55 09	55·138	55·18	[illegible]	4b^v	,,	,,	955·0
		* 53·52		2	,,	,,	963·5
* 53·02†	53·040	53·10	7	12	,,	,,	966·0
		* 52·60		2	,,	,,	968·4
		* 50·99		2	,,	,,	976·9
		* 50·85		2	,,	,,	977·6
		50·15		2	,,	,,	981·3
		* 47 07		2n	,,	,,	997·6
		46·60		2n	,,	,,	23000·1
* 43·00		43·01	4	4	,,	,,	019·1
* 42·36		42·37	3	2	,,	,,	022·5
* 41·15†	41·162	41·21	6	14b^v	,,	,,	028·9
		* 39·30		2n	,,	,,	038·8
		38·12		2	,,	,,	045·1
* 36·29		36·29	3	4	,,	,,	054·8
		* 35·64		2	,,	,,	058·2
		* 35·03		2	,,	,,	061·5
* 34·23		34·26	3	4	,,	,,	065·6
* 32 98†	32·985	33·05	6	12	,,	,,	072·4
* 32·56		32·46	3	2	,,	,,	077·7
		31·73		2	,,	,,	079·1
* 30·18†		30·28	3	12b^v	,,	,,	084·4
		27·26		2	,,	,,	102·9
		25·40		2	,,	,,	112·8
		24·80		2	,,	,,	116·2
		23·68		2	,,	,,	122·0
* 22·51		22·52	2	2	,,	,,	128·3
		22·20		2	,,	,,	130·0
* 20·46		20·45	2	2	,,	,,	139·3
		* 20·13		2	,,	,,	141·1
	18·803	18·81		2	1·18	,,	148·1
		16 4		2n	,,	,,	161·1
* 16·02		15·98	2	2	,,	,,	163·2
		* 15·00		2	,,	,,	168·6
* 14·06		14·07	3	4	,,	,,	173·6
		13·50		2n	,,	,,	176·6
		13·06		2	,,	,,	179·0
* 12·56		12·56	2	2	[illegible]	,,	181·7
		* 11·85		2n	,,	,,	185·5
		* 11·62		2	,,	,,	186·7
* 09·95	09·949	10 00	6	8	,,	,,	195·7

* Lockyer and Baxandall, 4361·58, 61·24, 60·77, 57·86, 57·64, 56·98, 56·14, 55·14, 53·54, 53·02, 52·68, 50·97, 50·86, 47·02, 43·02, 42·39, 41·19, 39·31, 36·33, 35·69, 35·06, 34·25, 32·96, 30·18, 22·53, 20·49, 20·15, 15·95, 15·02, 14·11, 12·58, 11·83, 11·66, 09·95; also 4388·32, 85·53, 83·30, 81·43, 77·33, 74·38, 71·98, 66·76, 47·64, 45·39, 31·28, 29·90.

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	λ+	$\frac{1}{\lambda}$ −	
4309·69		4309·68	3	2	1·18	6·4	22197·2
		* 08·60		2	,,	6·5	202·9
07·33		07·37	5	6	,,	,,	209·6
06·35		06·39	5	4	,,	,,	214·9
		06·07		2	,,	,,	216·5
		* 05·61		4	,,	,,	219·0
		04·98		2	,,	,,	222·4
		04·3		2n	,,	,,	226·1
03·70	4303·697		4		,,	,,	229·3
		02·69 Ca?		4	,,	,,	234·8
		* 02·31		2	,,	,,	236·8
		01·33		4b^r	,,	,,	242·1
		00·73		2	,,	,,	245·4
		00·25		2n	,,	,,	247·9
	* 4299·240	4299·13	2	2	,,	,,	253·7
		* 98·80		2	,,	,,	255·8
4298·17†		98·23	5	8	,,	,,	259·0
97·86	97·840	97·87	5	8	,,	,,	260·9
		* 97·26		2	,,	,,	264·1
96·28	96·266	96·31	5	10	,,	,,	269·4
* 91·97	91·978	92·01	6	10b^r	,,	,,	292·8
* 91·46		91·46	4	4	,,	,,	295·6
		91·13		2n	,,	,,	297·3
		90·45		2n	,,	,,	301·1
		89·87 Cr?		2	,,	,,	304·2
		89·51		2	,,	,,	306·2
		* 88·96		2	,,	,,	309·2
* 87·97		87·98	4	4b^r	,,	,,	314·5
* 86·57		86·57	4	4	,,	,,	322·2
		86·24		2n	,,	,,	323·9
		85·60		2	,,	,,	327·4
* 84·19	84·208	84·25	6	12	,,	,,	335·0
* 83·06		83·10	4	6	,,	,,	341·2
* 79·12		79·10	3	10	1·17	,,	362·9
* 77·12†	77·101	77·14	6	12	,,	,,	373·7
		* 76·47		2	,,	,,	377·3
		74·96 Cr?		2	,,	,,	385·5
		* 73·54		2	,,	,,	393·3
		* 72·90		2n	,,	,,	396·8
* 71·71	71·706	71·68	6	4	,,	,,	403·4
* 70·49		70·5	4	4b^r	,,	,,	410·0
* 69·92†		69·91	4	4	,,	,,	413·2
* 68·78†	68·787	68·83	6	14	,,	,,	419·3
		68·00		2	,,	,,	423·7
* 67·50†		67·55	3	4n	,,	,,	426·3
* 65·28		65·31	4b	4	,,	,,	438·5
		64·65		2n	,,	,,	442·1
		64·00		2	,,	,,	445·7
* 62·32	62·311	62·32	4	6b^r	,,	,,	454·9
61·37†		61·4	4	2n	,,	,,	460·0

* Lockyer and Baxandall, 4309·75, 08·61, 07·32, 06·40, 05·64, 03·70, 02·32, 4299·27, 98·79, 98·17, 97·85, 97·29, 96·30, 91·96, 91·45, 89·00, 87·93, 86·57, 84·19, 83·08, 79·12, 77·10, 76·50, 73·50, 72·93, 71·75, 70·51, 69·89 68·78, 67·48 65·25, 62·30, and also 4318·04, 06·76, 4278·53, 66·07, 61·32.

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	λ+	$\frac{1}{\lambda}$ −	
		4260·90		2	1·17	6·5	22462·7
		* 60·47		2n	,,	,,	465·1
		* 60·31		2n	,,	,,	466·0
* 4259·46†	4259·454	59·46	4s	4	,,	,,	470·7
* 57·53†	57·517	57·54	4s	4	,,	,,	481·9
		57·17		2	,,	,,	483·3
* 55·60		55·63	3	2	,,	,,	491·8
		54·51 Cr?		4b	,,	,,	498·0
* 53·02		53·00	3	2	,,	,,	506·3
* 51·45		51·45	2	2	,,	6·6	514·8
		49·49		2	,,	,,	525·6
		48·96		2	,,	,,	528·6
* 47·46		47·5	2	2b	,,	,,	536·7
		* 46·83		2	,,	,,	540·4
		43·98		2	1·16	,,	556·2
		43·02		4	,,	,,	561·5
* 41·48		41·45	4	4	,,	,,	570·3
* 40·53†		40·51	4	2	,,	,,	575·5
* 40·25†		40·23	4	2	,,	,,	577·0
* 39·12			3		,,	,,	583·2
		36·99		2	,,	,,	595·1
		* 36·78		2	,,	,,	596·2
* 35·90†	35·909		5		,,	,,	601·1
		35·47		4	,,	,,	603·5
* 34·70†	34·671	34·71	5	4	,,	,,	607·9
		34·3		2n	,,	,,	610·1
* 34·12	34·149	34·17	6	4	,,	,,	610·9
* 33·09†	33·007	33·12	6	4	,,	,,	616·9
* 32·62†	32·604	32·66	6	6	,,	,,	619·4
		32·20		6	,,	,,	621·8
		31·30		2	,,	,,	626·8
* 29·87		29·82	4	6	,,	,,	635·1
* 27·90†		27·90	4	4	,,	,,	645·8
	26·871	26·85 Ca?	8	10	,,	,,	651·7
26·78			4		,,	,,	652·1
* 25·40†	25·369	25·40	2	8n	,,	,,	659·9
		24·70		2	,,	,,	663·7
* 24·30		24·32	4	4	,,	,,	665·9
		22·77		2	,,	,,	675·5
* 22·49		22·50	2	2	,,	,,	676·1
* 21·17		21·20	2n	2n	,,	,,	683·3
		20·21		4	,,	,,	686·9
* 19·65		19·70	3	2	,,	,,	691·9
* 18·86†		18·87	4s	4	,,	,,	696·8
		18·65		2	,,	,,	697·7
		18·20		2	,,	,,	700·2
* 16·52		16·53	2	2	,,	,,	709·7
		15·77 Sr?		2	,,	,,	713·9
		14·12		2n	,,	,,	723·1
		13·8		2n	,,	,,	724·9
		13·17		2n	,,	,,	728·5

* Lockyer and Baxandall, 4260·46, 60·28, 59·47, 57·50, 55·59, 53·00, 51·42, 47·43, 46·91, 41·52, 40·54, 40·29, 39·15, 36·78, 35·92, 34·71, 34·18, 33·09, 32·68, 29·92, 27·92, 25·41, 24·36, 22·54, 21·22, 19·66, 18·89, 16·50.

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	λ+	$\frac{1}{\lambda}$ −	
4211·02		4211·02	2	2n	1·16	6·6	23740·6
10·55			2		,,	,,	743·3
* 09·98†	4210·002	10·02	5	12	,,	,,	746·4
* 05·23†	05·201	05·30	2	16	1·15	,,	773·4
* 04·67					,,	,,	776·5
		* 04·39	2	4	,,	,,	778·1
* 02·52	02·506	02·52	2	8	,,	,,	788·7
		* 01·08		2	,,	,,	796·8
* 00·35		00·38	4	2	,,	,,	800·9
		00·00		2n	,,	6·7	802·8
* 4198·78†		4198·80	4s	4	,,	,,	809·6
* 97·77†		97·79	4s	4	,,	,,	815·4
* 97·45†		97·47	2	2	,,	,,	817·3
		* 95·8		2n	,,	,,	826·7
* 94·17		94·21	2	2	,,	,,	835·7
* 91·70		91·80	5	6b	,,	,,	849·4
		91·11		4	,,	,,	853·3
		90·59		4	,,	,,	856·3
* 89·99	4190·011	90·03	5	6	,,	,,	859·6
* 87·82			2		,,	,,	872·1
* 86·95		86·93	2	2	,,	,,	877·1
* 83·59†		83·67	2	16	,,	,,	896·0
* 83·43	83·07		2		,,	,,	898·1
* 82·74	82·733	82·77	5	4	,,	,,	901·0
* 82·23		82·26	3	4	,,	,,	902·9
* 80·99†		81·03	2	2n	,,	,,	909·9
* 79·53		79·60	5	6	,,	,,	919·2
		79·22		2	,,	,,	921·2
		* 78·55		6	,,	,,	925·0
		* 77·75		2	,,	,,	928·6
* 77·25†		77·22	4	4	,,	,,	932·5
* 77·02			3		,,	,,	933·8
* 76·83			2		,,	,,	934·9
		76·00		2n	,,	,,	939·7
* 75·30†		75·30	2	2	,,	,,	943·7
		75·15		2	,,	,,	944·5
* 74·18†	74·155	74·19	4	4	,,	,,	949·1
* 71·45		71·46	4	4	,,	,,	965·8
* 69·40†		* 69·41	3	4	,,	,,	967·5
		* 69·06		2	,,	,,	979·5
		67·1		2b	1·14	,,	990·8
		66·32		2	,,	,,	995·3
		64·60		4	,,	,,	24005·2
		63·82		2n	,,	,,	009·7
		62·52	2	2	,,	,,	017·2
* 62·51		62·2		2n	,,	,,	019·0
* 60·57		60·57	2	2	,,	,,	028·5
* 59·84†	59·822	59·87	5	6	,,	,,	032·7
* 58·14							042·5

* Lockyer and Baxandall, 4210·00, 05·28, 04·67, 04·34, 02·50, 01·05, 00·30, 198·74, 97·74, 97·43, 95·73, 94·13, 91·69, 89·95, 87·74, 86·91, 83·60, 83·45, 82·74, 2·21, 80·95, 79·54, 78·53, 77·67, 77·19, 77·00, 76·85, 75·24, 74·13, 71·42, 69·37, 9·08, 67·15, 62·48, 60·48, 59·82, 58·11, and also 4260·00, 39·80, 23·15, 06·73, 4199·97, 9·75.

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	λ+	$\frac{1}{\lambda}$ −	
* 4156·00		4156·00	3	2″	1·14	6·7	24054·9
* 55·39			2		,,	,,	058·4
* 53·19		53·49	3	2	,,	,,	069·4
* 52·81		52·80	4	4	,,	,,	073·4
		52·3		2n	,,	,,	076·3
* 51·52		51·50	2	2	,,	,,	079·9
* 50·84		50·83	4	4	,,	6·8	084·8
* 49·02		49·00	3	4	,,	,,	095·3
		* 47·85		2b^r	,,	,,	102·1
* 43·02		43·07	2	2	,,	,,	130·0
* 42·75†		42·77	3	2	,,	,,	131·7
* 41·96		42·00	3	2	,,	,,	136·2
		* 41·51		2n	,,	,,	139·0
		40·22		2n	,,	,,	146·5
* 39·39		39·40	4	6	,,	,,	151·3
		* 38·27		4	,,	,,	157·9
		* 37·14		2b^r	,,	,,	164·5
* 36·52		36·53	4	4	,,	,,	168·1
* 36·25		36·21	4	4	,,	,,	169·8
		* 35·40		2	,,	,,	174·7
* 34·61†	4134·617	34·62	7	14	,,	,,	179·2
* 33·92		33·91	4	4	,,	,,	183·3
* 32·13†	32·123	32·15	7	16	,,	,,	193·8
* 31·32	31·297	31·32	2	2	,,	,,	198·6
		* 30·3		2b	1·13	,,	204·5
* 29·00		28·99	4	6	,,	,,	212·2
* 28·25†	28·152 ?	28·25	7	16	,,	,,	216·5
		26·07		2	,,	,,	229·3
* 24·23	24·196	24·26	4	4	,,	,,	240·1
* 23·65†		23·70	6	8	,,	,,	243·4
		* 23·30		4	,,	,,	245·6
* 21·13		21·15	2	2	,,	,,	258·3
* 20·69	20·655	20·69	4	6	,,	,,	261·0
* 19·58†	19·575	19·60	4	6	,,	,,	267·5
		* 19·25		2	,,	,,	269·5
* 18·73			4		,,	,,	272·5
* 18·34	18·320	18·38	5	10	,,	,,	274·8
16·85†		} 16·70	3	14	,,	,,	283·6
* 16·64†	16·631		6				284·9
* 15·32†	15·311	15·38	7	16	,,	,,	292·5
* 14·69		14·68	3	4	,,	,,	296·4
* 13·65	13·637	13·66	5	8	,,	,,	302·5
* 12·47†		12·50	3	6	,,	,,	309·4
11·92†	11·916	* { 12·10	8	{ 8n	,,	,,	311·7
		11·8		8n	..	,,	312·7
		* 10·93		2	..	..	318·6
09·94†	09·906	09·98	7	14			
		* 09·19		2			

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	λ+	1/λ −	
*4108·36		4108·38	4	6	1·13	6·8	24333·8
* 07·64†	4107·599	07·64	3	2	„	„	338·1
* 05·32†		05·38	6	8b	„	„	351·6
* 04·92†		04·92	4	6	„	„	354·2
* 04·55	04·516	04·59	4	6	„	„	356·4
		* 03·57		2	„	„	362·2
* 02·31†	02·285	02·31	6	10	„	„	369·9
		01·15		4	„	„	376·6
*4099·93†	4099·921	00·00	7	16	„	6·9	383·7
		*4099·03		2	„	„	389·1
* 98·54†	98·510	98·55	4	4	„	„	392·1
* 97·09†		97·08	3	2	„	„	400·7
* 95·64†	95·607	95·66	6	12	„	„	409·4
* 94·42		94·41	4	4	„	„	416·6
* 93·65		93·66	4	4	1·12	„	421·1
* 92·83†		92·86	6	8n	„	„	426·0
* 92·54†	92·532	92·53	4	4	„	„	427·9
* 92·09		92·10	3	4	„	„	430·4
* 90·70†	90·703	90·79	6	16	„	„	438·6
		85·81		4	„	„	468·0
		* 84·90		2	„	„	473·5
		* 83·07		6	„	„	484·5
		80·6		26	„	„	487·3
	77·849 Sr	77·86		2	„	„	515·8
* 72·30		72·32	4	2	„	„	549·2
* 71·67†	71·664	71·65	5	4	„	„	553·1
		* 70·92		2	„	„	557·6
		* 68·13		4	„	„	574·4
* 67·90		67·87	3	4	„	„	575·9
		67·13		2	„	„	580·4
		* 65·21		12	„	„	592·0
* 64·09	64·061	64·12	5	6	„	„	598·9
		* 62·86		2	„	„	606·3
		* 61·75		2	„	„	613·0
* 60·97		61·00	2	2	„	„	617·7
		58·95		2	„	„	630·0
* 57·21	57·206	57·22	6	8	„	„	640·5
		56·41		4	„	„	645·4
		* 53·76		8	1·11	„	661·6
		* 53·40		2	„	„	663·7
* 52·60		52·60	2	2	„	„	668·6
* 51·48†	51·485	51·52	5	10	„	„	675·4
* 51·11		51·13	5	10	„	„	677·6
		49·20		4	„	„	689·3
* 48·77		48·78	4	4	„	„	692·9
		47·60		2	„	„	699·1
* 47·05		47·08	2	2	„	„	702·4
		46·50		6	„	„	705·8
* 42·78	42·759	42·81	4	4	„	„	729·6
* 41·72			4		„	„	735·0

* Lockyer and Baxandall, 4108·32, 07·60, 05·33, 04·93, 04·52, 03·54, 02·25, 4099·94, 98·99, 98·50, 97·05, 95·60, 94·38, 93·61, 92·81, 92·55, 92·08, 90·74, 84·92, 83·07, 72·28, 71·67, 70·94, 68·16, 67·96, 65·54, 64·11, 62·92, 61·76, 61·00, 57·21, 53·81, 53·41, 52·60, 51·52, 51·10, 48·77, 46·99, 42·80, 41·66.

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	λ+	$\frac{1}{\lambda}$ −	
* 4040·46		4040·50	2	2	1·11	6·9	24742·7
		* 39·76		4	,,	7·0	746·9
		38·72		2	,,	,,	753·3
* 36·93†		36·95	2	8	,,	,,	764·2
* 35·77†		35·82	4	16	,,	,,	770·3
		34·91		2	,,	,,	776·7
* 33·01		33·04	2	2	,,	,,	788·2
* 32·62†		32·67	3	2	,,	,,	790·6
* 31·98	4031·961	32·05	4	6	,,	,,	794·6
* 31·37†		31·43	3	4	,,	,,	798·3
		30·32		2	,,	,,	804·9
* 30·04†		30·07	3	2	,,	,,	806·5
		29·2		2n	,,	,,	811·8
		28·27		2	,,	,,	817·5
		27·52		2n	,,	,,	822·2
		26·65		2	,,	,,	827·5
* 25·46		25·50	2	2	,,	,,	834·8
		* 24·60		2	,,	,,	840·2
* 23·50†	23·51	23·53	4	20	,,	,,	846·9
	* 22·038	22·05	2	2	,,	,,	856·0
		21·61		2	,,	,,	858·7
		* 20·70		2	,,	,,	864·3
		* 19·6		2b	,,	,,	871·1
		* 19·20		6	,,	,,	873·6
		17·44		6	,,	,,	884·5
		* 16·98		6	,,	,,	887·3
		15·81		2	1·10	,,	894·6
		15·51		2	,,	,,	896·4
* 15·20		15·23	2	2	,,	,,	898·2
		14·46		2	,,	,,	903·0
		* 13·68		2n	,,	,,	907·8
		13·55		2n	,,	,,	908·6
		12·70		2n	,,	,,	913·9
		11·74		2n	,,	,,	919·8
* 11·45		11·47	2	2	,,	,,	921·5
* 09·94		09·95	2	2n	,,	,,	931·0
		* 08·36		6	,,	,,	940·9
* 05·86†	05·838	05·90	4	16	,,	,,	956·4
* 03·70		03·66	3	2	,,	7·1	969·9
* 03·10†		03·12	3	10	,,	,,	973·5
		01·83		2	,,	,,	981·5
		01·29		2	,,	,,	984·8
* 00·24		00·25	2	2	,,	,,	991·4
		3999·40		6	,,	,,	996·7
* 3998·87	3998·847	98·90	6	8	,,	,,	25000·0
* 97·30†		97·28	3	10	,,	,,	009·8
* 92·95†	92·916	92·96	6	12	,,	,,	037·1
		92·14		2	,,	,,	042·1
		91·65		2	,,	,,	045·2
		* 91·30		2n	,,	,,	047·4

* Lockyer and Baxandall, 4040·43, 4039·76, 36·93, 35·77, 33·00, 32·64, 31·99, 31·36, 30·05, 25·47, 24·63, 23·48, 22·07, 20·73, 19·58, 19·18, 16·86, 15·26, 13·69, 11·50, 09·99, 08·33, 05·90, 03·70, 03·12, 03·24, 3998·91, 97·31, 92·95, 91·22, and also 4106·08, 01·65, 19·99, 4090·05, 88·00, 83·44, 78·10.

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
lberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	λ+	$\frac{1}{\lambda}$−	
·71†	3990·693	3990·72	6	12	1·10	7·1	25051·1
		* 89·93		6	,,	,,	056·0
·97		88·96	4	6	,,	,,	062·1
		* 88·22		2	,,	,,	066·7
		87·82		2	,,	,,	069·2
		85·40		8	,,	,,	084·5
·75†		84·73	4	6	,,	,,	087·6
		* 84·45		6	,,	,,	090·5
		84·08		2	,,	,,	092·8
		* 81·92		2	,,	,,	106·4
·66		80·69	4	6br	,,	,,	114·3
·59	79·540	79·56	4	6	,,	,,	121·3
·30		79·23	4	6	,,	,,	123·0
		* 77·88		10	,,	,,	131·9
		* 75·47		2	1·09	,,	147·2
79		73·80	4	16	,,	,,	157·7
49†		—	2		,,	,,	159·7
10		72·08	2	2n	,,	,,	168·5
		70·27	4	2	,,	,,	180·1
	68·588 Ca	68·60 Ca?	2	2	,,	,,	190·8
24		68·19	4	8	,,	,,	193·1
		*64·65	4	2n	,,	,,	215·8
77†		63·77		6	,,	,,	221·4
	61·652 Al	61·65 Al?	10	4	,,	7·2	234·8
		60·49		2n	,,	,,	242·4
		58·33			,,	,,	256·0
09†	52·073	52·11	4s	18	,,	,,	295·8
37		50·37	4	4	,,	,,	306·9
		*48·74		4	,,	,,	317·3
		47·93		2	,,	,,	322·5
		*46·04		2	,,	,,	334·7
		44·68		2	,,	,,	343·4
	44·133 Al	44·20 Al?	6	2	,,	,,	346·7
77		43·79	5	6	,,	,,	349·2
16		42·16	4	4	,,	,,	359·6
40†		41·43	3	4	,,	,,	364·4
75		40·74	2	2	,,	,,	368·7
48		39·48	4	4	,,	,,	376·9
		*39·00		2	,,	,,	380·0
35		38·34	4	4	,,	,,	384·2
68		37·69	4	4	,,	,,	388·4
		36·61		2n	1·08	,,	395·4
42		36·43	4	4	,,	,,	396·6
28		35·30	5	6	,,	,,	403·9
16		34·20	7	6	,,	,,	411·1
	33·[illegible]5 Ca	33·81 Ca?	6	6	,,	,,	413·6
50		31·49	4	8	,,	,,	428·4
19		30·21	2	4	,,	,,	436·8
		*29·89		6	,,	,,	438·8
		28·73		2	,,	,,	446·3

* Lockyer and Baxandall, 3990·72, 89·95, 88·98, 88·21, 84·78, 84·51, 81·78, 80·66, 79·61, 79·31, 77·88, 75·48, 73·79, 73·53, 72·12, 68·29, 64·64, 63·78, 52·12, 50·38, 48·79, 46·04, 43·81, 42·18, 41·40, 40·75, 39·49, 39·04, 38·37, 37·65, 36·43, 35·28, 34·18, 31·46, 30·19, 29·93, 28·64, and also 3990·05, 88·00, 83·44, 78·10, 23·28, 3995·08.

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	λ+	$\frac{1}{\lambda}$ −	
		*3926·68		4n	1·08	7·2	25459·6
		26·45		4	,,	,,	461·1
*3925·36	3925·350	25·40	4	6	,,	,,	468·2
* 24·84	24·768	24·86	5	8	,,	,,	470·7
* 22·58†	22·548	22·61	5	8	,,	,,	486·2
* 22·05	22·023	22·08	4	6	,,	,,	489·7
* 20·65		20·68	3	4	,,	,,	498·7
* 20·15		20·16	2	2	,,	,,	502·0
	19·600	—	2		,,	,,	505·6
* 16·55†		16·59	3	14	,,	,,	525·3
		*15·55		2	,,	,,	532·0
		*15·28		2	,,	,,	533·8
	*14·437	14·51	2	14	,,	,,	539·0
		*13·67		2n	,,	,,	544·3
* 13·03		13·07	4	4	,,	,,	548·3
* 12·36		12·37	5s	6	,,	,,	552·8
* 10·95		10·95	4s	4	,,	,,	562·0
* 10·01†	09·995	10·05	6	6	,,	,,	568·0
		09·85		4	,,	,,	569·2
		*08·5		2br	,,	7·3	578
		*07·35		2n	,,	,,	585·5
* 06·89†		06·93	4s	4	,,	,,	588·4
* 04·63		04·65	2	4	,,	,,	603·3
		04·27		2	,,	,,	605·7
* 03·42†		03·50	3	8n	,,	,,	611·0
02·71		02·70	2	4n	,,	,,	616·0
* 02·40†	02·371	02·41	7	6n	,,	,,	618·0
		* 01·86		2	,,	,,	621·5
* 01·30		01·30	5n	4n	,,	,,	625·2
		00·72	5n	2	,,	,,	629·0
* 00·33		00·32	2	4	,,	,,	631·6
*3899·30†		3899·32	2	8	,,	,,	638·6
* 98·15†	3898·082	98·2	6	6b	,,	,,	645·9
* 97·22		97·22	4	4	,,	,,	652·0
		*96·80		2	1·07	,,	654·8
* 96·29	96·259	96·32	4s	6	,,	,,	658·1
* 94·19†		94·18	4s	4n	,,	,,	672·0
* 93·03		93·03	6s	6	,,	,,	679·6
	* 92·471	92·63		2n	,,	,,	682·8
* 91·27		91·4	4b	4b	,,	,,	690·8
* 90·33†	90·298	90·35	6s	6	,,	,,	697·4
		*89·37		2	,,	,,	703·8
* 88·50		—	4n		,,	,,	709·6
* 88·23		88·20	2	2	,,	,,	711·4
86·72	86·691	86·73	4s	4	,,	,,	721·4
85·91†		85·95	2	2	,,	,,	726·6
		85·83		2	,,	,,	727·2
85·00 †		85·03	2	6	,,	,,	732·6
84·60		84·60	3	2	,,	,,	735·4

* Lockyer and Baxandall, 3925·36, 24·85, 22·57, 22·11, 20·67, 20·10, 16·57, 15·57, 15·30, 14·49, 13·71, 13·04, 12·35, 10·92, 09·96, 08·46, 07·33, 06·92, 04·51, 03·32, 02·45, 01·81, 01·28, 00·29, 3899·23, 98·17, 97·20, 96·83, 96·29, 94·16, 92·95, 92·53, 91·25, 90·30, 89·36, 88·47, 88·20, and also 3945·36, 28·07, 26·86, 26·64, 14·08, 11·90, 10·57, 09·58, 03·86, 3898·44, 95·86, 93·88, 91·88, 89·91, 87·69.

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	λ +	$\frac{1}{\lambda}$ −	
3884·04		3884·05	3	2	1·07		25739·0
		83·53		2	,,		742·5
		83·37		2	,,		743·5
		81·78		2	,,		754·1
		81·20		2	,,		757·9
		80·47		2	,,		762·8
79·82		79·79	3	2	,,		767·2
		78·85		1b	,,		773·5
		76·90		2n	,,		786·5
76·21†		76·25	5	4	,,		791·0
76·05†		76·03	4	4	,,		792·2
		75·78		2	,,		794·0
		75·52		2	,,		795·7
75·22†	3875·195	75·21	6	6	,,		797·8
		74·50		2	,,		802·5
73·80		73·79	2	4	,,		807·2
		73·38		2	,,		809·5
		72·90		2	,,		813·1
71·23		71·21	4	6	,,		824·3
70·72		70·73	2	4	,,		827·7
		70·14		2	,,		831·5
		68·20		2n	,,		844·5
67·77†		67·75	5	6	,,		847·4
67·50		67·49	2	2	,,		849·2
		66·90		6	,,		853·2
		66·52		2	,,		855·7
		65·9		4b	,,		860
65·02†	64·980	65·02	7	8	,,		865·8
64·02		64·00	4s	8	,,		872·6
62·37		62·35	4s	4	,,		883·6
		60·88		2n	,,		893·5
59·51		59·49	3	4	,,		902·8
58·83†		58·81	3	4	,,		907·4
		58·0		2n	,,		913
		57·31		2n	,,		917·5
56·00†	55·965	56·00	8	6n	1·06		926·4
55·50†	55·486	55·49	6	6	,,		929·7
		53·60		2	,,		942·5
52·27		52·21	2	4	,,		951·6
51·32		51·30	3	4	,,		957·9
		50·57		2	,,		962·9
		50·30		2n	,,		964·7
49·48	49·433	49·44	4	6	,,		970·4
47·46	47·453	47·50	5s	10	,,		983·8
45·03		45·03	2	2	,,		26000·3
44·58†	44·565	44·60	5s	8	,,	,,	003·3
		43·65		4	,,	,,	009·6
		42·88		4	,,		014·9
42·03		—	4	4	,,		020·6
40·88†	40·866	40·92	6	8	,,		028·3
40·56		40·56	5	6	,,		030·6
40·27		40·26	4	4	,,		032·5
39·53		39·53	4	6	,,		037·6
39·12†		39·13	4	6	,,		040·3
		37·90		2n	,,		048·2

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	λ+	$\frac{1}{\lambda}$—	
		3836·58		2n	1·06	7·3	26057·6
3836·20		36·19	4	4	,,	,,	060·2
35·70		35·69	4	4	,,	,,	063·6
		34 97		2	,,	,,	068·5
33·36†		33·38	2	2	,,	,,	079·4
32·97		33·00	2	2	,,	,,	081·9
		32·50		2	,,	,,	085·3
		31·98		2	,,	,,	088·9
		31·19		2	,,	,,	094·2
		30·42		2n	,,	,,	099·5
		29·77		4n	,,	,,	103·9
		28·9		6n	,,	,,	110
28·67†	3828·680	28·72	7	6n	,,	,,	111·3
		27·13		6	,,	,,	121·9
		26·95		2n	,,	,,	123·2
		25·47		2	,,	,,	133·3
		25·17		2	,,	,,	135·3
24·12		24·14	4	4	,,	,,	142·4
		23·90		2	,,	,,	144·0
		23·5		4b	,,	,,	147
23·35 †		23·37	4	4	,,	,,	147·7
23·00 †	23·008	23·05	4	4	,,	,,	149·9
		22·86		2	,,	,,	151·1
22·14†		22·21	5	6b*	,,	,,	155·8
21·63†	21·607	21·66	4	4	,,	,,	159·6
	20·589	—	4		,,	,,	166·7
20·41		—	2		,,	,,	167·9
20·10	20·087	20·14	4	4	,,	,,	170·0
		18·94		2	,,	,,	178·0
		18·48		4	,,	,,	181·1
18·37†	18·370	18·39	6	4	,,	,,	181·8
18·12		18·10	3	4	,,	7·4	183·6
17·98†		17·99	4	4	,,	,,	184·4
15·65		15·55	4	10	1·05	,,	200·8
13·63	13·612	13 63	6	8	,,	,,	214·4
		09·80		6	,,	,,	240·7
08·64†		08·70	5s	6	,,	,,	248·5
	08·136	—	8		,,	,,	252·1
07·64	07·626	07·69	4	6	,,	,,	257·5
	07·425	—	4		,,	,,	257·1
06·93		07·00	4	4	,,	,,	253·3
		06·65		2	,,	,,	262·4
		06·37		2	,,	,,	264·3
		05·12		2	,,	,,	273·0
		04·80		2	,,	,,	275·2
		04·6		2n	,,	,,	277
04·05		04·07	3	4	,,	,,	280·3
03·92		03·97	3	4	,,	,,	281·1
03·62†	03·613	03·64	5	6	,,	,,	283·3
		03·06		2	,,	,,	287·2
		01·4		2n	,,	,,	299
00·05	3799·992	00·07	5	8	,,	,,	308·1
		3799·43		2	,,	,,	312·3
		98·82		4	,,	,,	316·6
		98·41		2	,,	,,	319·4

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	$\lambda +$	$\frac{1}{\lambda} -$	
		3796·66		4	1·05	7·4	26331·5
		96·37		2	,,	,,	333·5
3795·12		95·08	7	10	,,	,,	342·3
		94·49		8	,,	,,	346·6
93·76†		93·76	4	4	,,	,,	351·7
		93·53		2	,,	,,	353·3
		91·47		2	,,	,,	367·6
90·62†‡	3790·593	90·64	3	6	,,	,,	373·5
90·46	90·448	90·48	5	6	,,	,,	374·6
		88·92		2	,,	,,	385·5
87·68		87·39	2	16	,,	,,	395·0
		84·98		2	,,	,,	412·8
84·84		84·88	2	2	,,	,,	413·7
		83·6		2b	,,	,,	422·5
		83·08		2n	,,	,,	426·1
82·70		82·70	2	2	,,	,,	428·8
		82·27		2n	,,	,,	431·8
		81·90		2	,,	,,	434·3
81·54		81·55	3	4	,,	,,	436·8
		80·85		2	,,	,,	441·7
79·80		79·86	3	6	,,	,,	448·8
78·83†	78·808	78·82	5s	10	,,	,,	455·9
78·48†		78·50	2	12	,,	,,	458·2
77·63†		77·63	2	4	,,	,,	464·2
77·31		77·30	2	4	,,	,,	466·5
		77·00		2	,,	,,	468·6
76·31		76·29	3	4	1·04	,,	473·5
75·85		75·80	3	4	,,	,,	476·9
75·34†		75·32	3	4	,,	,,	480·3
		74·82		6	,,	,,	483·9
74·27		74·29	2	4n	,,	,,	487·7
		73·92		2	,,	,,	490·3
		73·14		10	,,	,,	495·7
		72·30		2n	,,	7·5	501·5
71·87			3n		,,	,,	504·5
71·31†			2		,,	,,	508·5
71·11†		71·13	4	20	,,	,,	509·8
70·68		70·67	2	2	,,	,,	512·9
		70·10		2n	,,	,,	517·0
		69·97		2n	,,	,,	517·9
69·23		69·18	2	6	,,	,,	523·3
		67·84		8	,,	,,	532·9
		66·53		2	,,	,,	542·1
64·96		64·94	2	4	,,	,,	553·3
63·30		63·26	4	4	,,	,,	565·5
		61·55		4	,,	,,	577·3
		61·43		4	,,	,,	578·1
60·96		60·95	2	4	,,	,,	581·5
60·40†		60·40	2	10	,,	,,	585·4
		59·41		6	,,	,,	592·4
		58·90		2	,,	,,	596·0
		57·82		2	,,	,,	603·7
		57·51		2	,,	,,	605·9

‡ Ru 3790·65, Cr 3790·61.

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	λ+	$\frac{1}{\lambda}$ −	
3756·18		3756·15	2	2	1·04	7·5	26615·4
55·85		55·77	2	4n	”	”	617·9
		55·23		2n	”	”	622·0
		54·65		2n	”	”	626·1
53·44		53·38	2	4n	”	”	634·9
		53·00		2	”	”	637·8
51·94†		51·94	2	2	”	”	647·4
51·02†			4s		”	”	651·9
		50·43		8n	”	”	656·1
		50·10		12n	”	”	658·4
48·14		48·10	2	2	”	”	672·5
		47·28		2	”	”	678·5
46·02		46·00	4s	14	”	”	687·5
		43·77		8br	”	”	703·6
41·65†	3741·630	41·63	3	6n	”	”	718·8
		41·20		2	”	”	721·9
40·38†	40·374	40·39	3	4	”	”	726·7
38·93	38·901	38·92	4	4n	”	”	738·2
38·15	38·129	38·15	3	4	”	”	743·7
		37·60		2	1·03	”	747·6
		36·16		10	”	”	757·9
34·59		34·62	3	4n	”	”	769·1
		33·75		4n	”	”	775·2
32·88†		32·98	4s	14	”	”	781·1
		32·15		8	”	”	786·6
		31·20		2n	”	”	793·4
		30·36		2	”	”	799·5
		29·99		2	”	”	802·2
29·22		29·21	3	6	”	”	807·7
		28·51		10	”	7·6	812·9
27·49†		27·53	4	16br	”	”	820·0
		25·83		2	”	”	832·1
		25·1		2n	”	”	837
		24·6		2n	”	”	839
		23·75		2	”	”	847·1
23·52		23·49	3	2	”	”	848·8
22·76			4		”	”	855·2
22·27†	22·334	22·39	2	6n	”	”	857·3
22·15	22·136	22·18	2	4n	”	”	858·5
		21·55		2n	”	”	862·9
		21·1		2n	”	”	866
	19·124 } 19·051 }	19·07		6	”	”	880·9
		18·35		10	”	”	886·0
15·62‡		15·70	4s	20	”	”	905·2
14·12		14·12	2	4	”	”	916·7
		13·72		2	”	”	919·6
		12·69		4	”	”	927·0
		11·90		4	”	”	932·8
		11·28		8	”	”	937·3
08·88	08·852	08·86	3s	6	”	”	954·9
	06·167	06·20		6	”	”	974·3
05·19†	05·167	05·22	5	6	”	”	981·5

‡ Ni 3715·61.

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	λ+	$\frac{1}{\lambda}$−	
3704·85†	3704·831	3704·90	6	6b^v	1·03	7·6	26984·0
	04·664		2		”	”	985·4
03·71†		03·80	7	12b^r	”	”	992·0
		01·13		6	”	”	27011·1
		00·50		12	”	”	015·8
		00·35		6n	”	”	017·0
		3699·63		2	”	”	022·1
3696·00†	3695·995	96·02	6	8	1·02	”	048·7
95·48†	95·449	95·50	5	6n	”	”	052·5
		94·74		2n	”	”	057·9
92·36†	92·357	92·38	6	10	”	”	075·3
90·41†	90·407	90·43	5	8	”	”	090·3
88·22†	88·207	88·21	5	8	”	”	105·8
87·61†		87·60	5	6n	”	”	110·3
		86·83		2	”	”	116·0
86·40†	86·392	84·40	4	6	”	”	119·2
		85·31		6	”	”	127·2
84·83			3		”	7·7	130·7
		84·47		2	”	”	133·2
83·26	83·243	83·25	6	6	”	”	142·2
		81·5		2b	”	”	155
80·26	80·214	80·15	6	8n	”	”	164·7
	80·055		2		”	”	165·8
		77·47		2n	”	”	184·9
		77·17		2n	”	”	187·1
76·86‡	76·807	76·80	6n	6n	”	”	189·7
75·85†	75·835	75·83	5s	6	”	”	197·0
		75·58		2	”	”	198·9
		74·83		6	”	”	204·4
73·55†		73·50	6n	6n	”	”	214·3
72·53‡	72·519	72·51	4n	4n	”	”	221·6
	71·840		2		”	”	226·6
71·37†		71·33	4	6	”	”	230·2
69·57†		69·53	3	16	”	”	243·6
67·87	67·841	67·84	5n	6n	”	”	256·2
		65·9		2n	”	”	271
65·30	65·256	65·22	4	4n	”	”	275·5
63·73	63·694	63·68	5	6n	”	”	287·1
		61·53		12	”	”	303·3
		58·38		4	”	”	326·8
		57·92		2	1·01	”	330·2
		57·60		2	”	”	332·6
		56·80		4b	”	”	338·6
		54·8		2b	”	”	354
		53·61		2	”	”	362·5
		52·51		2n	”	”	370·7
49·13†	49·057	49·10	4	4	”	”	396·3
		47·45		2n	”	”	408·7
		46·98		4	”	”	412·3
		46·02		6	”	”	419·4
45·77		45·7	3	2b	”	”	421
44·88†		44·83	3	4	”	”	428·2
44·05	44·038	43·99	3	4	”	”	434·7

‡ Ru 3676·82, 72·53.

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	λ+	$\frac{1}{\lambda}-$	
		3643·27		2	1·01	7·7	27440·1
		42·82		2	,,	,,	443·5
3641·28		41·25	3	2b	,,	,,	455·2
40·25		40·20		2n	,,	,,	462·6
39·21†	3639·160	39·14	3	4	,,	7·8	471·0
38·57			2		,,	,,	475·5
37·95†		37·89	2	4	,,	,,	480·4
36·09		36·03	4	2n	,,	,,	494·5
		35·57		2	,,	,,	498·2
		34·06		2	,,	,,	509·6
		33·02		2	,,	,,	517·5
		29·45		2n	,,	,,	544·6
		27·83		8	,,	,,	556·9
		25·71		8	,,	,,	573·0
		24·98		2	,,	,,	578·6
22·82†		22·82	2	2n	,,	,,	595·0
		22·43		2	,,	,,	598·1
		21·35		8	,,	,,	606·2
		20·62		6	,,	,,	611·8
19·10		19·09	2s	12	,,	,,	623·4
		18·6		2	,,	,,	627
16·91		16·83	2	4	1·00	,,	640·4
		15·4		2b	,,	,,	652
		12·4		2b	,,	,,	675
		11·71		4	,,	,,	679·9
09·45†		09·40	3s	2	,,	,,	697·4
		08·07		2	,,	,,	707·8
05·75		05·73	3	4	,,	,,	725·8
		05·46		2	,,	,,	727·9
		05·0		2n	,,	,,	731
		04·25		2n	,,	,,	737·2
		03·10		2	,,	,,	746·0
00·20	00·166	00·16	2	2	,,	,,	768·6
		3597·1		2n″	,,	7·9	792
		95·77		2	,,	,,	802·6
3593·48†	3593·519	93·53	4	16	,,	,,	820·0
92·71		92·70	2	2	,,	,,	826·2
92·15†	92·159	92·19	4	18	,,	,,	830·5
89·91†	89·889	89·90	4	18	,,	,,	848·0
		88·25		6	,,	,,	860·8
		84·56		2	,,	,,	889·5
83·84†	83·840	83·85	2	2	,,	,,	895·1
83·00	82·953	82·97	2	2	,,	,,	901·9
81·00		80·94	2	2	,,	,,	917·7
		79·49		2	,,	,,	929·0
		78·78		4	,,	,,	934·6
78·01†	78·007	78·00	2	4	,,	,,	940·6
		77·80		2n	0·99	,,	942·2
		77·35		4	,,	,,	945·7
75·26†		75·25	2	2	,,	,,	959·1
74·92†	74·915	74·94	2	2	,,	,,	964·7
		74·51		8	,,	,,	968·0
73·69	73·652		2		,,	,,	974·3
		73·21		8	,,	,,	977·8
		72·82		2n	,,	,,	981·2

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	$\lambda +$	$\frac{1}{\lambda} -$	
		3572·50	0	2	0·99	7·9	27983·8
3571·82†		71·81	3	4	"	"	989·1
		71·38		2	"	"	992·4
71·18		71·18	3	2	"	"	994·0
		69·46		2	"	"	28007·5
69·11†		69·09	3	2	"	"	010·3
		68·45		2	"	"	015·4
66·33†		66·32	3	12	"	"	032·1
		63·90		2b	"	"	051·2
63·59		63·53	2	2n	"	"	053·9
62·31		62·31	2	2	"	"	063·7
		61·54		2	"	"	069·8
60·75†		60·78	2	8	"	"	075·9
		59·43		2	"	"	086·4
56·97		56·93	5s	20	"	"	106·1
56·42		56·40	3	4n	"	"	110·3
		55·90		2	"	"	114·4
55·32		55·30	3	2	"	"	119·0
53·43	3553·412	53·44	6	4	"	"	134·0
	51·669	51·69	2	2	"	8·0	147·7
		49·10		2n	"	"	168·1
		48·82		2n	"	"	170·4
		47·22		2	"	"	183·0
		46·96		2	"	"	185·1
45·52	45·419		3		"	"	197·0
45·34†	45·330	45·36	4	20r	"	"	198·0
43·68	43·631	43·63	3	4	"	"	211·5
		42·63		2n	"	"	219·6
		41·50		10	"	"	228·6
		40·66		2	"	"	235·3
		38·88		8	"	"	249·5
		35·54		2	0·98	"	276·2
		34·83		2	"	"	281·9
33·85†	33·820	33·86	6	8	"	"	296·2
		32·45		6	"	"	300·9
		31·63		4	"	"	307·5
30·91†		30·96	4	20	"	"	313·3
		30·6		2n	"	"	316
29·90†	29·876	29·89	4	6	"	"	321·5
		28·4		2b	"	"	333
		28·00		6	"	"	336·7
		27·4		2b	"	"	341
		25·96		2	"	"	353·1
24·89		24·89	3	16	"	"	361·7
24·38†			4		"	"	365·8
		23·8		2b	"	"	370
		23·35		2n	"	"	374·0
		22·75		2	"	"	378·9
		22·02		12	"	"	384·7
		20·72		6b	"	"	395·3
20·18†		20·19	4	14	"	"	399·5
		19·33		2	"	"	406·4
17·44†	17·436	17·46	4	20r	"	"	421·7
		16·16		2	"	"	432·0
		14·60		6	"	"	444·7

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	λ +	$\frac{1}{\lambda}$ −	
		3514·02		6	0·98	8·0	28449·4
		12·33		2	,,	,,	463·0
		11·57		2	,,	,,	469·2
		11·02		2	,,	,,	473·7
		09·18		6	,,	8·1	496·7
		07·69		6	,,	,,	500·6
		07·00		2	,,	,,	506·3
		06·70		4	,,	,,	508·7
3505·83†		05·84	2	4	,,	,,	515·8
04·57†		04·58	3	16	,,	,,	526·0
		03·35		2	,,	,,	535·9
01·65	3501·614	01·65	2	2	,,	,,	550·9
		01·03		2	,,	,,	554·8
		00·50		2	,,	,,	559·2
		00·00		4	,,	,,	563·3
3498·23		3498·34	2	2	0·97	,,	577·2
97·13	3497·081	97·23	2	14	,,	,,	586·5
93·34		93·27	2	12	,,	,,	618·1
		90·11		4	,,	,,	644·3
89·64	89·648	89·59	2n	2	,,	,,	648·1
		87·13		2	,,	,,	670·8
86·05†		86·09	2	12	,,	,,	677·5
		84·82		2	,,	,,	687·8
		84·48		2	,,	,,	690·5
		80·01		8	,,	,,	727·4
		79·10		2	,,	,,	735·0
		77·67		6	,,	,,	746·0
		77·5		4b	,,	,,	748
		76·38		4	,,	,,	757·4
		70·44		4	,,	8·2	806·6
		69·69		6	,,	,,	812·8
		66·75		4	,,	,,	837·3
		65·39		2	,,	,,	848·6
		64·34		2	,,	,,	857·3
		64·00		2	,,	,,	860·2
		63·50		2	,,	,,	864·3
		63·22		2	,,	,,	866·6
		61·71		2	,,	,,	879·2
		57·30		14	0·96	,,	916·1
	57·048		2n		,,	,,	918·1
		55·02		2	,,	,,	935·1
		53·23		8	,,	,,	950·2
		51·20		2	,,	,,	967·2
		47·7		2b	,,	,,	997
		45·95		2	,,	,,	29011·4
		44·46		2n	,,	,,	023·9
		42·48		2	,,	,,	040·6
		42·17		2	,,	,,	043·2
		37·90		2b	,,	,,	059·3
		36·52		2n	,,	,,	091·0
		35·52		2n	,,	,,	099·4
		34·15		2n	,,	,,	111·0
		33·96		2n	,,	,,	112·7
		32·1		2b	,,	8·3	128
		30·30		2n	,,	,,	143·7

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	λ+	$\frac{1}{\lambda}$−	
		3425·35		2n	0·96	8·3	29184·8
	3425·204	25·22	2n	4	,,	,,	186·9
		24·00		2	,,	,,	197·3
		22·40		2	,,	,,	210·9
		20·86		2	,,	,,	223·8
		20·35		2n	,,	,,	228·4
	18·676		2n		,,	,,	242·7
		17·22		2	0·95	,,	255·2
		15·00		2n	,,	,,	274·3
	14·370	14·35	2n	4	,,	,,	279·8
		09·10		4b	,,	,,	324·9
		08·15		2	,,	,,	333·2
	06·989	07·00	2n	2	,,	,,	343·0
		06·36		2	,,	,,	348·5
		06·19		2	,,	,,	350·0
	06·012		2n		,,	,,	351·5
		05·31		2	,,	,,	357·6
		05·12		2	,,	,,	359·2
		04·60		8	,,	,,	363·7
		03·50		2	,,	,,	373·2
		03·32		2	,,	,,	374·7
		02·73		2	,,	,,	379·9
		02·15		2n	,,	,,	384·9
		01·50		2	,,	,,	390·5
		00·54		4	,,	,,	398·8
		3398·40		2	,,	,,	417·3
		97·97		2	,,	,,	421·0
		97·69		2	,,	,,	424·2
		96·68		2	,,	,,	432·2
		95·7		2n	,,	8·4	441
		94·73		2	,,	,,	449·0
		92·81		6	,,	,,	465·7
		90·90		2	,,	,,	482·3
		89·0		2b	,,	,,	499
		87·95		2	,,	,,	508·0
		87·52		2	,,	,,	511·7
		85·9		2b	,,	,,	525·8
		84·73		2	,,	,,	536
		83·87		4	,,	,,	543·6
		82·67		4	,,	,,	554·0
		80·42		2	,,	,,	573·7
		79·5		2n	,,	,,	582
		77·74		4	0·94	,,	597·2
		77·49		2	,,	,,	599·4
		76·16		2	,,	,,	611·0
		74·13		2	,,	,,	628·8
		72·91		6	,,	,,	639·6
		71·60		2	,,	,,	651·4
		71·25		2	,,	,,	654·2
		70·60		2	,,	,,	659·9
		67·80		2	,,	,,	684·6
		66·98		2	,,	,,	691·8
	3365·670	65·68	6	2	,,	,,	703·3
		63·70		2	,,	,,	720·8
		61·67		6	,,	,,	738·7

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	λ+	$\frac{1}{\lambda}$−	
		3361·37		6	0·94	8·5	29741·4
	3356·471	56·51	4	2	,,	,,	784·5
		55·51		2	,,	,,	793·2
		54·85		2	,,	,,	799·1
		53·92		6	,,	,,	807·4
		49·56		6	,,	,,	846·2
		49·19		4	,,	,,	849·5
		48·57		2	,,	,,	855·0
		46·08		6	,,	,,	877·2
		42·04		4	,,	,,	913·3
		41·4		2n	,,	,,	919
		40·53		2	,,	,,	926·9
		38·00		12	0·93	,,	949·6
		35·65		2	,,	,,	970·7
		35·37		2	,,	,,	973·1
		33·88		2	,,	,,	986·6
	33·693		2		,,	,,	988·3
		32·30		2	,,	,,	30000·8
	29·983	30·02	6	4	,,	,,	021·5
		29·63		2	,,	,,	024·9
		29·10		2n	,,	,,	029·6
		28·60		2n	,,	,,	034·2
		28·13		2	,,	8·6	038·4
	24·514	24·57	2	2	,,	,,	070·9
		23·88		2	,,	,,	076·7
		23·12		2	,,	,,	083·6
	22·084		2		,,	,,	093·0
		21·72		10	,,	,,	096·3
		20·95		2	,,	,,	103·3
		20·33		2	,,	,,	110·9
		19·05		4	,,	,,	120·5
		18·04		4	,,	,,	129·7
		17·02		4	,,	,,	138·9
		15·65		2	,,	,,	151·4
		15·35		6	,,	,,	154·1
	14·980	15·00	2	6	,,	,,	157·4
	14·143		2		,,	,,	165·1
	13·141		2		,,	,,	174·3
	09·305	09·32	4	2	,,	,,	209·2
		08·62		4	,,	,,	215·5
		04·62		6	,,	,,	252·1
		01·82		2	,,	,,	277·8
		01·05		2	,,	,,	284·8
	3299·223		4		,,	,,	301·5
		3298·89		8	,,	,,	304·6
	98·276	98·26		2	,,	,,	310·3
		97·66			,,	,,	315·9
		96·19			,,	,,	329·5
		93·30		6	0·92	,,	356·1
	91·805	91·80	6	2	,,	,,	369·9
		91·18		2	,,	,,	375·6
	90·362	90·40	4	6	,,	,,	383·0
	89·515	89·52	4	8b^r	,,	,,	391·0
		89·11		4	,,	,,	394·7
	88·437	88·47	2	6	,,	8·7	400·7

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	λ+	1/λ−	
		3287·78		2	0·92	8·7	30407·0
		87·3		2b	,,	,,	411
		85·80		2	,,	,,	*425
	3285·133	85·29	2	6	,,	,,	430·7
	84·489	84·50	2	2	,,	,,	437·3
		83·46		2	,,	,,	446·9
	82·659	82·69	2	10	,,	,,	454·2
		81·92		4	,,	,,	461·3
	81·238	81·26	2	6	,,	,,	467·4
	79·976	80·02	2	16	,,	,,	479·1
	78·053		2n		,,	,,	497·1
	77·881	77·88	2n	6	,,	,,	497·8
		77·55		6	,,	,,	501·9
		77·21		4	,,	,,	505·0
	76·252	76·25	16	20r	,,	,,	513·9
		74·65		4	,,	,,	528·9
		74·35		2	,,	,,	531·6
	73·137	73·17	2	2	,,	,,	542·8
	71·759		4		,,	,,	555·9
	71·243	71·27	16	20r	,,	,,	560·6
		70·25		10	,,	,,	569·9
		69·07		2	,,	,,	581·9
	67·823	67·84	16	20r	,,	,,	592·6
	66·027	66·06	2	10	,,	,,	609·3
		64·5		2b	,,	,,	624
		63·45		8	,,	,,	633·7
	62·422	62·45	2	2	,,	,,	643·2
		61·90		2	,,	,,	648·3
		61·73		2	,,	,,	649·9
	61·198	61·20	2	2	,,	,,	654·9
		59·80		2	0·91	,,	668·0
	59·658	59·63	2	2	,,	,,	669·5
		58·02		8	,,	,,	684·8
	56·892		2		,,	,,	695·4
	55·769	55·72	2	2	,,	,,	706·2
	54·836	54·90	4	10	,,	,,	714·5
		53·00		2	,,	,,	732·1
	51·886	52·01	2	10	,,	,,	732·6
	50·894	50·90	2	10	,,	8·8	751·9
	49·690	49·71	2	8	,,	,,	763·3
		48·74		2	,,	,,	772·3
		48·00		2	,,	,,	779·4
		47·69		2	,,	,,	782·3
		47·5		2n	,,	,,	784
		42·14		2	,,	,,	835·0
		41·30		2	,,	,,	843·0
		40·90		2	,,	,,	846·8
		40·00		2	,,	,,	855·4
		39·17		2	,,	,,	863·3
	37·990	38·08	4	12	,,	,,	874·2
		36·72		2	,,	,,	886·7
		34·64		4	,,	,,	906·5
	33·878	33·98	2	8	,,	,,	912·9
		33·67		6	,,	,,	915·8
	33·300	33·36	4	2	,,	,,	918·9

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	λ+	$\frac{1}{\lambda}$ –	
	3232·064	3232·10	2	6	0·91	8·8	30931·0
		31·09		2	,,	,,	940·5
	30·765	30·80	2	2	,,	,,	943·5
	29·724	29·75	2	2	,,	,,	953·5
		29·30		2n	,,	,,	957·7
		28·7		2b	,,	,,	963
		28·3		2b	,,	,,	965
	27·520	27·54	2	2	,,	,,	974·7
		27·05		6b*	,,	,,	979·3
	26·223	26·22	2	2	,,	,,	987·2
		24·20		2	,,	,,	31006·6
		22·97		2	,,	,,	018·4
		21·52		2	,,	,,	032·4
	18·985	18·98	2	2	0·90	,,	056·9
	17·240	17·23	2	12	,,	,,	073·8
	15·487		2		,,	,,	090·7
		14·86		8	,,	,,	096·8
		14·10		2	,,	,,	104·1
	12·550	12·55	2	4	,,	,,	119·1
		11·70		2	,,	,,	127·3
	10·546		2		,,	,,	138·5
	10·253	10·21	2	2	,,	,,	141·6
	08·464	08·46	2	8b*	,,	,,	158·8
	07·521	07·52	8	2	,,	,,	167·9
		06·4		2b	,,	,,	179
	05·689	05·70	6	2	,,	8·9	185·5
	05·378	05·45	2	2	,,	,,	188·0
		04·30		2	,,	,,	199·1
		02·80		2	,,	,,	213·8
	02·495	02·50	12	2	,,	,,	216·7
		01·8		4b	,,	,,	223·5
	3199·934	3199·95	2	2	,,	,,	241·7
	98·121	98·09	2	2	,,	,,	259·6
		97·65		2	,,	,,	264·1
		96·66		4	,,	,,	273·7
		95·7		2b	,,	,,	283
	94·030	94·06	2	2	,,	,,	299·4
		93·29		4	,,	,,	306·8
		92·78		4	,,	,,	311·8
	90·798	90·80	10	16r	,,	,,	331·2
		89·87		2	,,	,,	340·3
	88·624	88·60	2	10r	,,	,,	352·7
		88·18		4	,,	,,	356·9
	87·820	87·78	8	10r	,,	,,	361·0
		86·93		4	,,	,,	369·3
	85·507	85·46	20	4r	,,	,,	383·5
	84·097	84·04	20	4r	,,	,,	397·4
	83·525	83·48	18	4r	,,	,,	403·1
		82·71		8	,,	,,	410·9
		79·50		2	0·89	9·0	442·5
		77·75		2	,,	,,	459·8
		76·2		2b	,,	,,	475
		74·61		8	,,	,,	490·9
		74·17		6	,,	,,	495·3
		72·34		2	,,	,,	513·5

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	A	Spark	$\lambda +$	$\frac{1}{\lambda} -$	
		3171·82		2	0·89	9·0	31518·6
		70·35		2	,,	,,	533·3
		68·62		2	,,	,,	550·5
	3168·244	68·24	2	6	,,	,,	554·4
		67·55		10	,,	,,	561·1
		66·48		2	,,	,,	571·8
		65·96		4	,,	,,	577·0
	64·945	64·91	2	4	,,	,,	587·5
		63·85		2	,,	,,	598·1
		63·13		6	,,	,,	605·2
		62·81		6	,,	,,	608·5
		62·46		2	,,	,,	612·0
		61·42		6	,,	,,	622·4
		60·87		4	,,	,,	628·9
		59·45		4	,,	,,	642·1
		58·01		4	,,	,,	656·5
		56·35		2	,,	,,	673·1
		55·51		6	,,	,,	681·7
		54·9		2n	,,	,,	688
		51·42		8	,,	,,	722·7
		48·86		4	,,	,,	748·5
		46·95		4	,,	9·1	767·7
		46·40		6	,,	,,	773·2
	46·086	46·10	2	4	,,	,,	776·4
		45·48		4	,,	,,	782·5
		44·85		4	,,	,,	787·9
		43·61		4	,,	,,	801·5
	42·596	42·67	4	8b	,,	,,	810·0
		42·33		4	,,	,,	813·4
		41·63		4	0·88	,,	821·5
		41·23		2	,,	,,	825·6
	39·862	39·88	2	10	,,	,,	839·3
		38·17		4	,,	,,	856·6
	37·304		2		,,	,,	865·4
		36·64		12	,,	,,	872·1
	35·060	35·08	2	12	,,	,,	888·1
	33·455	33·48	10	10	,,	,,	904·4
		32·90		2	,,	,,	910·2
		32·72		2	,,	,,	912·0
	30·408	30·40	10	12	,,	,,	935·7
		28·81		4	,,	,,	951·9
		28·40		4	,,	,,	956·1
	26·338	26·31	10	8	,,	,,	977·3
		25·52		8	,,	,,	985·6
	25·402		10		,,	,,	986·8
		25·20		8n	,,	,,	988·8
		23·49		2	,,	,,	32006·3
	23·020	23·01	2	10	,,	,,	011·2
	21·261	21·27	2	8	,,	,,	029·2
	20·849		2		,,	,,	033·4
		20·36		8	,,	,,	038·5
		19·44		2	,,	,,	047·9
	18·406	18·51	16	12r	,,	,,	058·0
		16·90		6	,,	,,	074·1
		16·18		2	,,	,,	081·5

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	λ+	$\frac{1}{\lambda}$−	
	3113·038	3113·19	2	8	0·88	9·2	32113·0
	10·826	10·82	2	12r	"	"	136·7
		09·51		1	"	"	150·2
	09·381		2		"	"	151·5
	09·283		2		"	"	152·5
		08·81		4	"	"	157·4
		07·85		2n	"	"	167·4
		06·9		2n	"	"	177
		06·08		2n	"	"	185·7
		05·67		2n	"	"	189·9
		05·03		4	"	"	196·5
	02·415	02·39	20	12r	"	"	224·9
	01·038	01·09	2	10	0·87	"	237·6
	3094·793		2n		"	"	313·6
		3094·33		12	"	"	307·9
		93·23		16r	"	"	319·2
		89·78		2	"	"	355·6
		88·1		2b	"	"	373
		86·61		4	"	"	388·8
		86·33		2	"	"	391·8
		83·31		6	"	"	423·5
		82·65		6	"	"	430·4
		82·20		2	"	"	435·1
		81·39		2	"	"	443·7
		81·13		4	"	"	446·4
		80·4		2n	"	"	454·0
		79·0		2n	"	"	469
		78·75		2n	"	"	471·5
		76·12		2	"	9·3	499·2
		75·7		2b	"	"	504
		75·3		2b	"	"	508
		74·77		2	"	"	513·5
		72·96		2	"	"	532·6
		70·31		2	"	"	560·0
		69·82		2	"	"	565·9
		67·20		10	"	"	593·7
		66·5		2b	"	"	601
		65·71		4	"	"	609·6
		63·80		10	"	"	629·9
		62·80		4	0·86	"	640·5
		62·31		2	"	"	645·8
		60·60		2n	"	"	664·0
		59·3		2b	"	"	678
		57·55		2	"	"	696·6
		56·46		2	"	"	708·3
		56·03		2	"	"	712·9
		54·00		8	"	9·4	734·5
		53·48		10	"	"	740·1
		52·3		2b	"	"	753
		51·44		2n	"	"	762·0
		50·85		6	"	"	768·4
		49·00		6	"	"	788·2
		48·76		10r	"	"	790·8
		45·10		2	"	"	830·5
		43·62		4	"	"	846·2

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	λ+	$\frac{1}{\lambda}$−	
		3043·27		2	0·86	9·4	32850·0
		42·39		8	,,	,,	859·9
		41·52		6	,,	,,	868·9
		39·9		2n	,,	,,	886
		38·63		4	,,	,,	900·1
		35·28		2	,,	,,	936·5
		34·55		2	,,	,,	944·4
		33·99		8r	,,	,,	950·5
		33·55		8r	,,	,,	955·3
		32·30		2	,,	,,	968·9
		31·15		2n	,,	,,	981·5
		29·65		2	,,	,,	997·7
		28·15		6	,,	,,	33014·1
		27·70		4	,,	,,	019·0
		25·08		6	,,	,,	037·6
		23.99		6	,,	9·5	059·4
		22·70		6	0·85	,,	073·5
		22·29		2	,,	,,	078·0
		20·4		2b	,,	,,	099
		19·1		2b	,,	,,	113
		16·81		6	,,	,,	136·2
		16·20		4	,,	,,	144·8
		16·03		4	,,	,,	146·8
		14·87		8	,,	,,	159·4
		13·12		6	,,	,,	178·7
		12·09		6	,,	,,	189·9
		09·60		2	,,	,,	217·5
		08·61		8	,,	,,	228·4
		07·37		4	,,	,,	242·1
		06·57		4	,,	,,	250·9
		05·87		4	,,	,,	258·7
		03·50		8	,,	,,	285·0
		02·72		2	,,	,,	293·6
		01·82		4″	,,	,,	303·6
		01·28		10r	,,	,,	309·7
		2999·57		2	,,	,,	328·6
		99·30		2	,,	,,	331·6
		98·00		2	,,	,,	346·1
		96·7		2b	,,	9·6	360
		96·05		8	,,	,,	367·7
		94·59		8	,,	,,	384·0
		89·72		2n	,,	,,	438·3
		89·67		6	,,	,,	438·9
		89·35		4	,,	,,	442·5
		88·07		8	,,	,,	456·6
		85·25		6	,,	,,	487·3
		83·62		8	,,	,,	506·7
		83·10		2	,,	,,	512·6
		82·82		4	0·84	,,	515·7
		82·00		4	,,	,,	524·9
		81·27		8	,,	,,	533·1
		79·6		2b	,,	,,	552
		79·16		2	,,	,,	556·9
		78·25		4	,,	,,	567·1
		77·60		2	,,	,,	574·5

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	$\lambda +$	$\frac{1}{\lambda} -$	
		2976·55		10r	0·84	9·6	33586·4
		76·20		8	"	"	590·3
		75·70		8	"	"	595·9
		74·06		6	"	"	614·4
		72·31		10	"	"	634·2
		71·65		2	"	"	641·7
		70·53		2	"	9·7	654·3
		69·93		2	"	"	661·1
		68·40		12r	"	"	678·4
		68·15		4n	"	"	681·2
		67·65		2	"	"	687·0
		64·1		2b	"	"	728
		63·34		2	"	"	735·9
		62·87		2	"	"	741·3
		62·10		2	"	"	750·0
		60·87		2	"	"	764·1
		58·68		6	"	"	789·1
		57·74		10	"	"	799·9
		56·70		2	"	"	811·8
		55·65		6	"	"	823·8
		54·45		2	"	"	837·5
		54·02		2	"	"	843·0
		53·85		2	"	"	843·4
		52·12		10r	"	"	864·2
		51·65		4	"	"	869·7
		50·40		8	"	"	884·0
		49·70		2	"	"	892·1
		49·24		8	"	"	897·4
		48·15		8	"	"	909·9
		46·60		2	"	"	927·7
		45·9		2b	"	"	936
		44·68		10r	"	9·8	949·7
		43·70		2	"	"	961·0
		43·25		2	"	"	966·2
		42·48		4	0·83	"	975·1
		41·51		10r	"	"	988·3
		38·35		4	"	"	34022·3
		37·82		2	"	"	029·0
		37·13		4	"	"	037·0
		35·99		2	"	"	050·3
		34·48		8	"	"	067·7
		33·95		4	"	"	073·9
		32·42		8	"	"	091·7
		32·00		4	"	"	096·5
		31·73		4	"	"	099·8
		30·96		8r	"	"	108·7
		30·25		6	"	"	117·0
		29·12		2	"	"	130·1
		26·50		10	"	"	160·7
		25·40		6	"	"	173·5
		24·79		10r	"	"	180·7
		24·14		10r	"	"	188·2
		23·47		6	"	"	196·1
		22·75		2n	"	"	204·6
		20·50		10	"	"	230·9

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	$\lambda +$	$\frac{1}{\lambda} -$	
		2920·11		8	0·83	9·8	34235·4
		18·32		6	,,	,,	256·4
		17·41		8	,,	,,	267·1
		16·00		6	,,	,,	283·6
		15·46		6	,,	,,	290·0
		14·97		4	,,	,,	295·8
		14·40		6	,,	,,	302·5
		13·85		2	,,	,,	309·0
		13·17		2n	,,	,,	316·9
		12·7		2b	,,	,,	322·5
		11·78		4	,,	,,	333·3
		11·17		8r	,,	,,	340·6
		10·50		8r	,,	,,	348·5
		10·15		8r	,,	,,	352·6
		08·96		8r	,,	,,	366·6
		08·56		6	,,	,,	371·3
		07·60		8	,,	,,	382·7
		06·60		8r	,,	,,	394·5
		05·75		6	,,	,,	404·6
		05·13		6	,,	,,	411·9
		04·23		2	,,	,,	422·6
		03·70		2″	0·82	,,	428·9
		03·20		8r	,,	,,	434·8
		00·06		2	,,	,,	472·1
		2899·5		2b	,,	,,	479
		98·02		4	,,	,,	496·4
		96·98		2	,,	10·0	508·8
		96·31		8	,,	,,	516·7
		95·74		2	,,	,,	523·5
		94·96		2	,,	,,	532·8
		94·78		2	,,	,,	534·9
		93·47		10r	,,	,,	550·5
		92·82		10r	,,	,,	558·3
		92·51		6	,,	,,	562·0
		91·78		10r	,,	,,	570·8
		90·69		4	,,	,,	583·8
		90·28		4	,,	,,	588·7
		89·71		10r	,,	,,	595·6
		88·36		10	,,	,,	611·6
		87·30		4	,,	,,	624·4
		87·08		4	,,	,,	627·1
		84·91		12r	,,	,,	653·1
		84·20		4	,,	,,	661·7
		82·60		10	,,	,,	680·9
		80·92		6	,,	,,	701·1
		80·14		10	,,	,,	710·5
		79·26		6	,,	,,	721·1
		78·40		2	,,	,,	731·5
		78·13		2	,,	,,	734·8
		77·80		8	,,	,,	738·8
		77·05		4	,,	,,	747·8
		75·78		6	,,	,,	763·2
		74·34		2	,,	,,	780·6
		73·30		6	,,	,,	793·2
		71·61		2	,,	,,	813·5

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	$\lambda+$	$\frac{1}{\lambda}-$	
		2870·66		2	0·82	10·1	34825·1
		70·27		4	,,	,,	829·3
		70·08		4	,,	,,	832·1
		69·22		12	,,	,,	842·6
		68·24		2	,,	,,	854·4
		66·75		2n	,,	,,	872·6
		66·57		2n	,,	,,	874·8
		64·60		8	0·81	,,	898·7
		64·0		2b	,,	,,	906
		63·1		2b	,,	,,	917
		62·41		4	,,	,,	923·5
		61·53		2	,,	,,	935·2
		60·11		2	,,	,,	953·0
		58·1		2n	,,	,,	968
		55·39		6	,,	,,	35011·3
		54·41		12	,,	,,	023·4
		53·85		2	,,	,,	040·3
		53·01		2n	,,	,,	040·5
		52·63		6	,,	,,	045·2
		51·36		4	,,	,,	060·8
		50·33		10	,,	,,	073·5
		49·19		8	,,	,,	087·5
		47·65		10	,,	10·2	106·4
		46·70		2	,,	,,	118·1
		46·40		2	,,	,,	121·8
		45·37		8	,,	,,	134·6
		44·95		2	,,	,,	139·8
		44·4		2n	,,	,,	147
		43·97		4n	,,	,,	151·9
		43·35		2	,,	,,	159·5
		42·83		2	,,	,,	166·0
		42·50		2n	,,	,,	170·1
		42·2		2n	,,	,,	174
		41·20		8	,,	,,	186·1
		40·72		4	,,	,,	192·1
		40·24		4	,,	,,	198·0
		39·52		2	,,	,,	207·0
		38·64		2	,,	,,	217·9
		38·16		4	,,	,,	223·8
		36·62		8	,,	,,	243·0
		35·7		2n	,,	,,	254
		35·55		4n	,,	,,	256·3
		34·75		6n	,,	,,	263·2
		32·55		2	,,	,,	293·6
		31·8		4b	,,	,,	303
		31·15		2n	,,	,,	311·1
		30·9		2b	,,	,,	314
		30·52		6	,,	,,	319·0
		28·75		2	,,	,,	341·1
		27·1		2n	,,	,,	362
		26·02		8n	,,	,,	375·2
		25·20		2n	,,	,,	385·5
		24·59		2	0·80	,,	393·1
		22·6		8b	,,	10·3	419
		21·26		6	,,	,,	434·8

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	$\lambda +$	$\frac{1}{\lambda} -$	
		2819·56		6	0·80	10·3	35456·2
		18·70		2n	"	"	467·0
		17·61		8	"	"	481·7
		16·30		2n	"	"	497·2
		15·70		2	"	"	504·8
		15·10		2	"	"	512·3
		15·03		4	"	"	513·1
		14·40		2	"	"	521·3
		13·41		2	"	"	533·8
		12·9		2n	"	"	540
		12·32		2	"	"	547·5
		12·12		2	"	"	550·1
		11·74		2	"	"	554·9
		10·39		12	"	"	571·9
		09·66		6	"	"	581·2
		08·85		2	"	"	591·5
		08·39		6	"	"	597·3
		08·2		2n	"	"	600
		07·05		2n	"	"	614·4
		06·95		2	"	"	615·6
		06·67		2	"	"	619·1
		06·2		2b	"	"	626
		05·69		6	"	"	631·6
		04·58		2	"	"	645·6
		03·60		10	"	"	658·4
		02·93		8	"	"	666·6
		01·15		6n	"	"	689·3
		00·23		2	"	"	701·0
		2799·59		10	"	"	709·0
		98·88		8	"	10·4	718·2
		98·40		2	"	"	724·3
		97·93		8	"	"	730·4
		97·60		2n	"	"	734·5
		97·12		8	"	"	740·6
		95·61		4	"	"	760·0
		95·02		4b	"	"	767·5
		94·50		2n	"	"	774·2
		94·02		2	"	"	780·3
		92·6		2bv	"	"	798·5
		91·7		4bv	"	"	810
		90·2		2b	"	"	829
		88·8		2b	"	"	847
		88·11		6n	"	"	856·2
		87·2		4b	"	"	868
		87·18		4	"	"	868·1
		86·0		4b	"	"	883
		84·40		8b	"	"	904·0
		84·1		2b	"	"	907
		83·12		2	0·79	"	920·5
		82·70		2	"	"	925·9
		81·69		12n	"	"	939·0
		80·25		2b	"	"	957·6
		78·75		8bv	"	"	977·0
		78·23		2	"	"	983·7
		77·86		10	"	"	988·5

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	λ +	$\frac{1}{\lambda}$ −	
		2776·4		2n	0·79	10·4	36007
		75·69		8	"	"	016·6
		75·11		4	"	10·5	026·0
		74·81		6	"	"	028·0
		74·40		8	"	"	033·3
		73·82		2	"	"	040·9
		72·2		10b^{v}	"	"	062
		71·60		8n	"	"	069·7
		71·12		2	"	"	075·9
		69·84		6	"	"	092·7
		68·69		10	"	"	107·7
		68·24		6	"	"	113·4
		67·25		6n	"	"	126·4
		66·59		10	"	"	135·1
		65·81		14b^{v}	"	"	145·2
		64·45		2n	"	"	165·0
		63·8		2n	"	"	171·5
		62·7		4n''	"	"	186
		61·53		2n	"	"	201·3
		60·62		10r	"	"	213·3
		60·26		8	"	"	218·0
		59·25		6n	"	"	231·3
		58·95		4	"	"	235·2
		58·67		4n	"	"	238·9
		56·7		4n	"	"	265
		56·5		4n	"	"	267
		55·20		4n	"	"	284·5
		53·54		16b^{v}	"	"	306·4
		52·27		4n	"	"	323·1
		51·93		4n	"	"	336·0
		50·2		4b	"	10·6	350
		48·6		2n	"	"	371·5
		47·55		10	"	"	385·5
		46·00		2	"	"	406·0
		44·63		2	"	"	424·2
		43·85		4	"	"	434·5
		42·80		6	"	"	448·5
		42·53		6	"	"	452·1
		41·69		2	0·78	"	463·2
		41·1		4b	"	"	471
		39·80		8	"	"	488·4
		39·30		4n	"	"	495·1
		37·42		2	"	"	519·7
		36·78		2	"	"	528·7
		36·28		2n	"	"	535·4
		35·55		2n	"	"	545·1
		34·43		4n	"	"	560·1
		34·05		4	"	"	565·2
		33·8		2n	"	"	568·5
		33·15		4n	"	"	577·2
		32·35		4n	"	"	588·0
		31·50		2	"	"	599·3
		31·30		2	"	"	602·0
		29·81		10	"	"	622·0
		28·06		2	"	"	645·5

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	λ+	$\frac{1}{\lambda}$ −	
		2726·67		6	0·78	10·6	36664·1
		24·80		2	"	"	689·2
		24·52		2	"	"	693·0
		23·59		6	"	"	705·5
		23·34		6	"	"	708·9
		22·73		2	"	"	717·1
		22·40		2	"	"	721·6
		21·9		2n	"	"	728
		21·30		2	"	"	736·4
		20·35		2n	"	"	749·3
		18·55		2n	"	"	773·6
		18·1		2n	"	"	780
		17·56		2	"	"	787·0
		15·80		16	"	"	810·9
		15·20		2n	"	"	819·0
		14·31		6	"	"	831·1
		13·20		6	"	"	886·1
		13·0		4n	"	"	849
		12·4		8n	"	"	857
		11·88		10	"	"	864·1
		10·30		4	"	"	885·6
		09·2		2b	"	"	900·5
		08·68		2	"	"	907·7
		08·00		10	"	"	916·9
		06·87		10	"	"	932·3
		06·34		8	"	"	939·6
		06·24		8	"	10·7	940·0
		05·34		6	"	"	953·2
		03·26		2	"	"	981·6
		02·31		14	"	"	994·7
		01·66		2	"	10·8	37003·5
		01·16		10	"	"	010·3
		01·01		6	"	"	012·3
		2699·82		2n	"	"	027·7
		99·27		2	"	"	036·3
		98·83		2	0·77	"	042·3
		97·86		2	"	"	055·6
		97·31		4	"	"	063·2
		97·16		2n	"	"	065·2
		96·65		4n	"	"	072·3
		94·85		6n	"	"	097·0
		94·6		2n	"	"	100·5
		93·1		2n	"	"	121·2
		90·91		12	"	"	151·4
		90·41		10	"	"	158·3
		89·99		10	"	"	164·1
		88·82		10	"	"	180·2
		88·12		10	"	"	189·9
		87·90		8	"	"	193·0
		87·7		6b	"	"	196
		86·60		2	"	"	211·0
		85·77		6	"	"	222·5
		85·22		6	"	"	230·1
		84·91		6	"	"	234·4
		83·5		2b	"	"	254

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	λ+	$\frac{1}{\lambda}$ −	
		2683·21		10	0·77	10·8	37258·0
		82·98		10	,,	,,	261·2
		82·60		2	,,	,,	266·5
		80·54		4	,,	,,	295·1
		79·39		14	,,	,,	311·1
		78·66		12	,,	10·9	321·2
		77·91		12	,,	,,	331·7
		77·25		2	,,	,,	340·8
		76·3		4b	,,	,,	354
		74·27		2nr	,,	,,	382·5
		73·40		8n	,,	,,	394·6
		72·11		14	,,	,,	412·7
		70·38		10	,,	,,	436·9
		69·08		2	,,	,,	455·1
		68·70		2	,,	,,	460·5
		68·18		4n	,,	,,	467·8
		67·65		2	,,	,,	475·3
		66·9		4b	,,	,,	486
		66·10		2	,,	,,	497·0
		65·5		2n''	,,	,,	505·5
		63·42		18	,,	,,	534·8
		62·45		2	,,	,,	548·5
		61·67		10	,,	,,	559·5
		59·74		8	,,	,,	586·7
		59·10		8	,,	,,	597·7
		58·62		4	,,	,,	602·6
		57·40		6	,,	,,	619·9
		55·82		16	,,	,,	642·3
		54·50		2n	0·76	,,	661·0
		53·94		2	,,	11·0	668·8
		52·90		10	,,	,,	683·6
		52·03		2n	,,	,,	695·9
		51·70		2n	,,	,,	700·6
		51·1		2n	,,	,,	709
		50·55		2n	,,	,,	717·0
		49·50		16	,,	,,	732·0
		48·04		12	,,	,,	752·8
		47·82		4	,,	,,	755·9
		47·37		2n	,,	,,	762·3
		46·3		2n	,,	,,	778
		45·90		14	,,	,,	783·3
		45·38		2n	,,	,,	790·7
		44·50		16	,,	,,	803·3
		43·8		4b	,,	,,	813
		43·23		4	,,	,,	821·5
		42·82		4	,,	,,	827·4
		42·32		14	,,	,,	834·5
		41·05		16	,,	,,	852·7
		40·40		2	,,	,,	861·0
		38·65		4b	,,	,,	887·2
		38·02		?	,,	,,	896·2
		37·81		?	,,	,,	899·2
		37·30		2n	,,	,,	906·6
		36·13		2n	,,	,,	923·1

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	λ+	$\frac{1}{\lambda}-$	
		2635·73		6	0·76	11·0	37929·1
		35·52		4n	"	"	932·2
		34·64		2n	"	"	944·8
		34·02		2n	"	"	953·7
		33·31		2n	"	"	964·0
		32·50		2n	"	"	975·7
		30·72		12	"	11·1	38001·3
		29·88		10n	"	"	013·4
		28·88		8n	"	"	027·9
		28·35		2n	"	"	035·6
		28·2		2n	"	"	038
		25·73		2	"	"	073·5
		25·00		8n	"	"	084·1
		23·86		8n	"	"	100·7
		22·85		8n	"	"	115·4
		21·9		8b	"	"	129
		20·4		2b	"	"	151
		20·2		2b	"	"	154
		19·55		2n	"	"	163·7
		18·5		2b	"	"	178
		17·28		6n	"	"	196·5
		16·75		6n	"	"	204·2
		16·31		8	"	"	210·6
		15·50		8n	"	"	222·5
		14·49		6	"	"	237·3
		13·9		4b	"	"	246
		12·4		4b	"	"	268
		11·6		4n	"	"	280
		11·35		6n	"	"	283·3
		10·8		8b	"	"	291
		2509·91		2	0·75	"	304·4
		09·68		2	"	11·2	307·8
		08·11		6n	"	"	330·7
		07·5		2n	"	"	340
		06·60		2n	"	"	353·0
		05·8		4b	"	"	365
		03·52		6n	"	"	398·3
		03·05		6n	"	"	405·2
		02·40		4n	"	"	414·8
		01·20		8n	"	"	432·5
		00·65		2n	"	"	440·7
		00·15		2	"	"	448·1
		98·9		2n	"	"	467
		97·33		4	"	"	489·8
		96·55		2n	"	"	501·5
		95·20		16	"	"	521·4
		94·0		2n	"	"	539
		93·8		2n	"	"	542
		93·18		16	"	"	549·9
		92·32		2	"	"	564·3
		91·68		2	"	"	573·8
		91·3		2b	"	"	579
		90·7		2b	"	"	588
		90·3		2b	"	"	594
		88·89		2	"	"	614·4

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	λ+	$\frac{1}{\lambda}$ −	
		2588·55		2	0·75	11·2	38620·5
		88·22		[illegible]	„	11·3	625·3
		87·5		4b	„	„	636
		85·02		10	„	„	673·1
		83·7		2b	„	„	693
		83·12		6	„	„	701·5
		81·95		2	„	„	719·1
		78·53		4	„	„	770·4
		77·78		10	„	„	781·7
		77·39		2	„	„	787·5
		76·56		6	„	„	800·1
		76·20		2	„	„	805·5
		74·61		10	„	„	829·5
		74·14		4	„	„	836·6
		73·3		4b	„	„	849
		72·85		4n	„	„	856·1
		72·0		6b	„	„	869
		71·14		10	„	„	881·9
		68·47		4n	„	11·4	922·3
		68·18		2	„	„	926·6
		67·6		4b	„	„	935·5
		66·70		6n	„	„	949·2
		66·13		4	„	„	957·9
		65·8		2n	„	„	963
		65·65		4	„	„	965·1
		65·32		2	„	„	970·2
		64·90		4	0·74	„	976·5
		64·25		6n	„	„	986·4
		63·45		6b	„	„	998·6
		62·87		6	„	„	39007·4
		62·3		4b	„	„	016
		61·3		2b	„	„	031
		60·25			„	„	047·4
		59·20		2n	„	„	063·4
		58·99		2	„	„	066·5
		56·87		2	„	„	098·9
		56·00		10	„	„	112·2
		55·6		2b	„	„	118
		54·93		2	„	„	128·6
		54·30		14	„	„	138·3
		53·76		8	„	„	146·6
		53·11		12	„	„	156·6
		52·75		2n	„	„	162·1
		52·35		2n	„	„	168·2
		51·83		6	„	„	176·6
		50·7		2n	„	„	194
		49·76		4	„	„	208·0
		49·36		14	„	„	214·2
		48·80		12	„	11·5	222·7
		48·28		14	„	„	230·7
		46·40		2	„	„	259·6
		46·00		2	„	„	265·8
		45·79		2	„	„	269·1
		45·54		4	„	„	272·9
		44·40		4n	„	„	290·5

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	λ+	$\frac{1}{\lambda}-$	
		2543·75		2	0·74	11·5	39300·5
		43·05		2	,,	,,	311·4
		42·6		10b	,,	,,	318
		41·90		2	,,	,,	329·2
		41·1		2b	,,	,,	341·5
		39·3		8b	,,	,,	369
		37·67		6	,,	,,	394·7
		35·20		2	,,	,,	433·1
		34·60		8	,,	,,	442·5
		34·34		2	,,	,,	446·5
		34·04		4	,,	,,	451·2
		33·93		4	,,	,,	452·9
		32·07		4 br	,,	,,	481·9
		31·71		2	,,	,,	487·5
		31·33		2	,,	,,	493·4
		30·22		4	,,	11·6	510·7
		28·97		14	,,	,,	530·2
		28·59		14	,,	,,	536·1
		28·00		18	,,	,,	545·4
		26·80		16	,,	,,	564·2
		25·63		2	,,	,,	582·5
		25·44		2	,,	,,	585·4
		25·07		10	,,	,,	591·2
		23·76		4	,,	,,	611·8
		23·50		2	,,	,,	615·9
		22·95		2	,,	,,	624·5
		22·60		6	,,	,,	630·1
		22·50		4	,,	,,	631·7
		21·62		12	,,	,,	645·6
		21·30		10	,,	,,	650·5
		20·85		2n	,,	,,	657·6
		20·40		2n	,,	,,	664·6
		19·77		6n	,,	,,	674·9
		19·3		2b	,,	,,	683·5
		18·7		2b	,,	,,	691
		18·07		2n	,,	,,	701·3
		17·54		2	0·73	,,	709·7
		17·20		4	,,	,,	715·1
		16·19		14	,,	,,	731·0
		15·76		2	,,	,,	737·8
		15·20		2	,,	,,	746·6
		14·70		12	,,	,,	754·6
		13·7		2b	,,	,,	770
		13·43		2n	,,	,,	774·6
		12·95		2n	,,	,,	782·3
		12·5		2b	,,	,,	789
		12·05		4	,,	11·7	796·5
		11·74		4	,,	,,	801·3
		11·3		2b	,,	,,	808
		10·90		2	,,	,,	814·6
		10·37		2	,,	,,	823·0
		09·91		2	,,	,,	830·4
		08·93		2	,,	,,	845·8
		07·87		4	,,	,,	862·8
		07·70		3	,,	,,	865·5

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	$\lambda +$	$\frac{1}{\lambda} -$	
		2506·97		4	0·73	11·7	39877·1
		06·27		10	,,	,,	888·2
		05·63		2	,,	,,	898·4
		05·32		2	,,	,,	903·9
		05·02		2	,,	,,	908·1
		04·34		4	,,	,,	918·9
		03·98		2	,,	,,	924·7
		03·33		2n	,,	,,	935·1
		03·08		10	,,	,,	939·0
		02·44		2	,,	,,	949·3
		01·67		4	,,	,,	961·6
		01·20		2	,,	,,	969·1
		00·10		2n	,,	,,	986·7
		2499·30		2	,,	,,	999·4
		99·12		2	,,	,,	40002·3
		98·3		2b	,,	,,	015
		97·08		2	,,	,,	035·0
		95·85		2	,,	,,	054·7
		94·20		2n	,,	,,	081·2
		93·66		4	,,	,,	089·9
		92·4		2b	,,	,,	110·3
		91·24		2	,,	11·8	128·9
		90·74		2	,,	,,	136·9
		89·86		2	,,	,,	151·1
		88·66		4	,,	,,	170·5
		88·20		4	,,	,,	177·9
		87·6		2b	,,	,,	188
		85·55		2	,,	,,	220·7
		84·27		2	,,	,,	241·5
		83·40		2	,,	,,	255·5
		83·11		10	,,	,,	260·3
		82·39		10	,,	,,	272·0
		80·68		2n	,,	,,	299·7
		79·60		12	,,	,,	317·3
		79·09		12	,,	,,	325·5
		78·64		8	,,	,,	332·9
		76·33		4	,,	11·9	370·4
		75·92		6	,,	,,	377·1
		75·49		6	,,	,,	384·1
		74·8		2b	,,	,,	395
		72·94		2	,,	,,	425·8
		71·18		6	,,	,,	454·6
		69·85		2n	0·72	,,	476·4
		69·46		2	,,	,,	482·8
		68·69		2	,,	,,	495·4
		65·34		10	,,	,,	550·5
		64·14		6	,,	,,	570·2
		62·99		8	,,	,,	589·2
		61·57		8	,,	,,	612·5
		60·65		2n	,,	,,	627·7
		59·40		4	,,	12·0	648·3
		59·31		2	,,	,,	649·8
		58·35		8	,,	,,	665·7
		57·85		2	,,	,,	674·0
		57·50		8	,,	,,	679·7

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	λ+	$\frac{1}{\lambda}$–	
		2456·56		2	0·72	12·0	40695·6
		53·90		2	,,	,,	739·5
		53·41		10	,,	,,	747·5
		52·83		2	,,	,,	757·2
		52·1		2b	,,	,,	769
		51·6		2b	,,	,,	778
		50·80		2	,,	,,	791·0
		50·69		2	,,	,,	792·8
		50·29		4	,,	,,	799·5
		48·50		2	,,	,,	829·3
		47·70		10	,,	,,	842·7
		46·75		8	,,	,,	858·5
		45·61		2	,,	,,	877·6
		45·38		2	,,	,,	881·4
		45·00		10b	,,	,,	887·8
		42·65		2n	,,	12·1	927·0
		41·96		2	,,	,,	938·8
		41·71		2	,,	,,	942·8
		41·40		2	,,	,,	948·0
		39·81		2	,,	,,	974·7
		39·35 Fe		6	,,	,,	982·4
		39·17		2	,,	,,	985·4
		39·09		4	,,	,,	41003·5
		36·62		2	,,	,,	028·4
		35·56		4	,,	,,	046·2
		33·05		6	,,	,,	088·5
		32·06		2	,,	,,	105·3
		31·65		2	,,	,,	112·3
		30·10		10	,,	,,	138·5
		28·35		4	,,	,,	168·1
		27·80		4	,,	12·2	177·4
		27·37		6	,,	,,	184·7
		26·18		2	,,	,,	205·0
		24·83		2n	,,	,,	227·8
		24·23		2	,,	,,	248·1
		23·47		2	,,	,,	251·0
		23·27 Fe		2	,,	,,	254·4
		23·11		2	,,	,,	257·1
		22·06		4	,,	,,	275·0
		21·15		4	0·71	,,	290·6
		20·20		4	,,	,,	306·7
		18·80		2	,,	,,	330·6
		17·60		10br	,,	,,	361·2
		16·84		4	,,	,,	366·4
		15·40		2	,,	,,	388·8
		15·23		4	,,	,,	391·8
		14·00		14	,,	,,	412·8
		13·15		2	,,	,,	427·4
		12·80		4	,,	12·3	433·3
		08·53		4	,,	,,	506·8
		08·01		2	,,	,,	515·8
		07·70		2	,,	,,	521·1
		07·25		12	,,	,,	528·9
		05·96		2	,,	,,	551·2
		05·30		16	,,	,,	562·7

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	λ+	$\frac{1}{\lambda}-$	
		2403·35		4	0·71	12·3	41596·4
		02·01		4	,,	,,	619·6
		00·99		4	,,	,,	637·5
		2399·77		12	,,	,,	658·4
		98·23		2n	,,	,,	685·3
		97·74		2	,,	,,	693·7
		97·2		2n	,,	,,	703
		97·1		2n	,,	,,	705
		96·62		2	,,	12·4	713·1
		95·1		2n	,,	,,	740
		93·70		18	,,	,,	763·9
		92·8		2n	,,	,,	780
		91·33		2	,,	,,	805·4
		90·56		4	,,	,,	818·8
		89·79		8	,,	,,	832·3
		89·01		2	,,	,,	845·9
		88·35		2	,,	,,	857·1
		88·0		2b	,,	,,	864
		87·04		2	,,	,,	880·5
		86·51		2	,,	,,	889·9
		85·92		6	,,	,,	900·2
		85·70		4	,,	,,	904·0
		85·05		2b	,,	,,	915·4
		84·09		8	,,	,,	932·5
		83·55		2n	,,	,,	941·9
		82·59		16	,,	,,	958·8
		81·00		10	,,	12·5	986·7
		80·3		2n	,,	,,	999
		79·24		10	,,	,,	42017·8
		77·0		2b	,,	,,	057
		75·9		2n	,,	,,	077
		74·75		2	,,	,,	097·2
		74·2		2n	,,	,,	108
		73·15		10	0·70	,,	125·6
		72·67		2	,,	,,	132·4
		72·25		6	,,	,,	159·5
		71·19		18	,,	,,	160·6
		67·71		6	,,	,,	222·4
		66·96		2	,,	,,	235·7
		66·53		4	,,	,,	243·5
		66·40		16	,,	,,	245·8
		65·73		2	,,	,,	257·3
		62·71		4	,,	,,	311·7
		60·42		6	,,	,,	352·8
		58·82		14	,,	12·6	381·6
		57·89		6	,,	,,	398·2
		57·60		2b	,,	,,	403·4
		56·3		2n	,,	,,	427
		55·3		2	,,	,,	445
		54·74		4	,,	,,	455·0
		52·25		10	,,	,,	500·0
		51·64		6	,,	12·7	510·9
		51·33		4	,,	,,	516·5
		49·87		8	,,	,,	542·9
		49·37		2n	,,	,,	543·8

VANADIUM—*continued.*

Arc Spectrum*		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	λ+	$\frac{1}{\lambda}$−	
		2348·30		8	0·70	12·7	42571·5
		47·57		2	,,	,,	584·8
		47·20		8	,,	,,	591·3
		46·92		6	,,	,,	596·4
		46·41		10	,,	,,	605·8
		43·91		6	,,	,,	651·0
		43·20		10	,,	,,	664·2
		42·26		10	,,	,,	681·2
		41·49		2	,,	,,	695·3
		40·6		2b	,,	,,	711
		39·9		2n	,,	,,	724
		39·02		2	,,	12·8	740·3
		37·46		6	,,	,,	768·8
		37·28		8	,,	,,	772·1
		36·20		6	,,	,,	791·8
		35·59		6	,,	,,	803·0
		35·44		2	,,	,,	805·8
		34·30		10	,,	,,	826·8
		33·70		6	,,	,,	833·6
		31·86		10	,,	,,	871·4
		31·38		6	,,	,,	880·4
		30·53		12	,,	,,	896·0
		30·3		6n	,,	,,	900
		29·03		8	,,	,,	923·8
		28·2		2b	,,	,,	939·0
		26·13		4	,,	12·9	977·1
		25·22		10	0·69	,,	993·9
		23·92		12	,,	,,	43017·8
		19·91		4	,,	,,	092·2
		19·07		8	,,	,,	107·8
		18·10		10	,,	,,	125·9
		17·61		6	,,	,,	135·0
		16·8		2b	,,	,,	150
		15·8		2b	,,	,,	169
		15·07		2	,,	,,	182·3
		14·25		8	,,	,,	197·8
		12·5		2b	,,	,,	230
		11·40		8	,,	13·0	251·0
		09·91		8	,,	,,	278·7
		09·14		2	,,	,,	293·3
		08·87		2	,,	,,	298·2
		08·35		2b	,,	,,	308·1
		06·45		2n	,,	,,	343·8
		04·89		2	,,	,,	374·3
		03·29		2	,,	,,	403·2
		02·30		2	,,	,,	421·8
		2297·91		8	,,	,,	504·8
		96·93 C?		4	,,	,,	523·3
		96·39		2	,,	13·1	533·6
		95·91		2	,,	,,	542·6
		95·65		4	,,	,,	547·6
		95·55		4	,,	,,	549·5
		95·03		6	,,	,,	559·4
		92·91		8	,,	,,	599·6
		92 64		6	,,	,,	604·8

VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	λ +	$\frac{1}{\lambda}$ −	
		2291·5		2n	0·69	13·1	43626
		90·62		6	„	„	636·7
		89·27		4	„	„	656·4
		88·69		4	„	„	674·7
		88·12		4	„	„	691·1
		87·99		4	„	13·2	693·3
		85·50		6	„	„	740·9
		84·98		2	„	„	750·9
		84·80		2	„	„	754·4
		84·6		2n	„	„	758
		83·85		4	„	„	772·5
		83·42		4	„	„	780·8
		82·92		2	„	„	790·3
		81·66		4	„	„	814·6
		81·27		4	„	„	822·0
		80·38		4	„	„	847·1
		79·78		4	„	„	850·7
		79·40		2	„	„	858·0
		78·99		4	„	„	865·9
		78·16		2	„	„	882·1
		75·97		2	0·68	„	924·1
		75·62		2	„	„	930·9
		75·28		4	„	„	937·5
		73·69		2	„	13·3	968·1
		73·09		4	„	„	978·2
		71·92		2	„	„	44002·3
		71·22		2	„	„	015·8
		69·2		2n	„	„	055
		68·35		4	„	„	069·0
		67·7		2n	„	„	084
		64·43		2	„	„	147·9
		63·7		2n	„	„	162
		62·44		2	„	13·4	186·8
		61·9		2	„	„	197
		61·44		2	„	„	212·3
		60·90		2	„	„	216·8
		58·83		4	„	„	257·3
		57·04		2	„	„	292·5
		53·00		2	„	„	371·9
		51·60		2	„	„	399·5
		51·20		2	„	„	407·4
		50·8		2n	„	„	415
		50·50		2n	„	13·5	421·1
		49·18		6	„	„	448·1
		43·50		2	„	„	543·8
		41·57		8	„	„	598·2
		40·66		4	„	„	616·1
		37·25		2	„	13·6	684·2
		32·97		10	„	„	769·8
		30·05		4	„	„	828·4
		29·81		4	0·67	„	833·3
		28·33		4	„	„	863·2
		22·79		4	„	13·7	974·8
		21·58		2	„	„	999·2
		20·29		2	„	„	45025·5

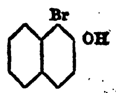
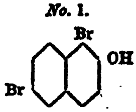
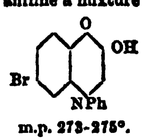
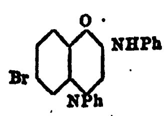
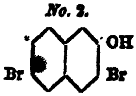
VANADIUM—*continued.*

Arc Spectrum		Spark Spectrum	Intensity and Character		Reduction to Vacuum		Oscillation Frequency in Vacuo
Hasselberg	Rowland and Harrison	Exner and Haschek	Arc	Spark	λ+	1/λ −	
		2218·51		6	0·67	13·7	45061·5
		18·07		4	„	„	070·5
		17·48		6	„	„	082·3
		16·11		6	„	„	110·6
		15·92		2n	„	„	114·3
		14·11		6	„	13·8	151·3
		10·40		2	„	„	226·8
		10·10		2	„	„	233·0
		09·31		4	„	„	249·3
		09·02		4	„	„	255·3
		07·83		2	„	„	279·6
		04·60		2	„	„	345·9
		02·62		4	„	13·9	386·3
		01·77		4	„	„	446·1
		2199·72		2	„	„	446·4
		99·57		2	„	„	449·5
		98·66		2	„	„	468·8
		98·13		2	„	„	479·3
		95·82		2n″	„	„	527·1
		94·98		2	„	„	544·6
		93·03		2	„	„	585·2
		91·20		2	„	„	608·0
		90·60		2	„	14·0	639·6
		90·30		2	„	„	641·8
		87·00		2	„	„	710·7
		86·02		2	„	„	731·1
		85·45		2	„	„	743·2
		84·25		2	„	„	768·3
		82·30		2n	„	„	809·1
		81·95		2	„	„	816·6
		77·3		2n	0·66	„	915
		77·0		2n	„	14·1	921
		75·9		2	„	„	944
		73·2		2	„	„	46001
		71·9		2	„	„	047·5
		66·2		2n	„	„	134
		63·7		2n	„	14·2	207
		61·6		2n	„	„	248
		51·9		2	„	„	456
		51·1		2	„	14·3	474
		50·9		2	„	„	478
		48·4		2	„	„	532
		47·5		2	„	14·4	551
		46·0		2	„	„	584
		43·1		2	„	„	627
		42·0		2	„	„	671
		40·1		2	„	„	712·5
		39·8		2	„	14·5	719
		38·1		2	„	„	756
		37·3		4	„	„	774
		34·1		4	„	„	844
		33·0		2	„	„	868
		31·8		2	„	„	894

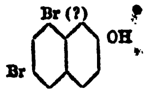
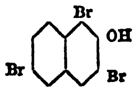
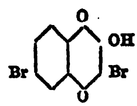
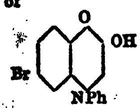
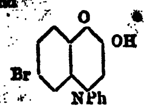
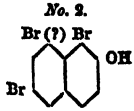
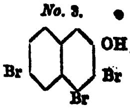
Isomeric Naphthalene Derivatives.—Report of the Committee, consisting of Professor W. A. Tilden (*Chairman*) *and* Dr. H. E. Armstrong (*Secretary*). (*Drawn up by the Secretary.*)

The investigation of the bromo-derivatives of β-naphthol, referred to in several previous reports, has been continued during the year with the assistance of Mr. W. A. Davis, and practically completed. The results are embodied in the following tables :—

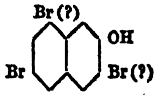
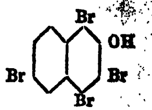
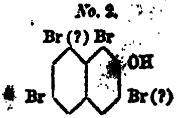
Isomeric Bromo-β-Naphthols.

	Bromo-derivative	Properties	Convertible by HNO_3 into	Remarks
Monobromo-β-naphthols.	*No.* 1.  Ex β-naphthol and Br_2.	Slender needles, easily soluble in acetic acid, m.p. 82°.	1-Nitro-2-naphthol, m.p. 103°.	Readily dissolves in iodhydric acid, yielding β-naphthol.
	No. 2.  Ex dibromo No. 1 and iodhydric acid at ordinary temperature.	From benzene in long needles, m.p. 127°; from glacial acetic acid in massive crystals, m.p. 84°, which effloresce in air. *Acetate*, m.p. 103°.	1-Nitro-2-naphthol, m.p. 103°.	
Dibromo-β-naphthols.	*No.* 1.  Ex β-naphthol in glacial acetic acid and $2Br_2$.	From glacial acetic acid in lustrous needles + 1 mol. $C_2H_4O_2$, m.p. 84°; from light petroleum in slender needles, m.p. 106°. *Acetate*, lustrous plates, m.p. 125°.	(1) 1-Nitro-6-bromo-2-naphthol; from alcohol in slender yellow needles, m.p. 122°. (2) 1-Bromo-β-naphthaquinone (m.p. dependent on rate of heating), and 4 : 6-dibromo-β-naphthaquinone, m.p. 171°; both quinones crystallise from ethylic acetate in magnificent red prisms.	Both the naphthol and the dibromoquinone, m.p. 171°, yield 4-bromophthalic acid on oxidation with dilute nitric acid. Both the mono- and dibromoquinone yield with aniline a mixture of  m.p. 273-275°.  m.p. 206°.
	No. 2.  Ex tribromo-naphthol No. 1, and iodhydric acid at 100°.	From toluene in silky needles, m.p. 137·5°. *Acetate*, ex acetone in transparent rhombs, m.p. 127°.		When heated with alcohol and H_2SO_4 6·5 hours at 100° yields 55 per cent. of *ether*, $C_{10}H_5Br_2OEt$, m.p. 98°.

Isomeric Bromo-β-Naphthols—continued.

Bromo-derivative	Properties	Convertible by HNO_3 into	Remarks
No. 3.  Ex tribromo-β-naphthol No. 2 and iodhydric acid.	From benzene and light petroleum in long needles, m.p. 134·5°. *Acetate*, crystallises in small colourless needles, m.p. 87–88°.		With alcohol and H_2SO_4 6 hours at 100° yields 61·0 per cent. of *ether*, which crystallises from alcohol in silky tufts of needles, m.p. 68°.
Tribromo-β-naphthols.			
No. 1.  Ex β-naphthol in acetic solution and $3Br_2$.	From acetic acid in *non-efflorescent*, lustrous needles, m.p. 155°. *Acetate*, from ethylic acetate in long, slender, lustrous needles, m.p. 184°. *Benzoate*, m.p. 187°.	(1) 1-Nitro-3 : 6-dibromo-β-naphthol, slender golden needles from alcohol; melts and decomposes at about 156°. (2) 3 : 6-Dibromo-1 : 2-naphthaquinone, from ethyl acetate in deep-red rhombs, or orange-red needles, m.p. 150°; changes in air into  m.p. 213°. With aniline the latter yields an *additive compound*, $C_{10}H_4O_3Br_2 + C_6H_5NH_2$, crystallising from benzene in red prisms and decomposing at 195°.	On oxidation with dilute HNO_3 the dibromoquinone yields 4-bromophthalic acid; anhydride, m.p. 106°. With aniline the quinone yields a mixture of  m.p. 273–275°. and  m.p. 206°.
No. 2.  By action of bromine (excess) on *dry* β-naphthol at 100°.	From acetic acid in small *efflorescent* needles + 1 mol. $C_2H_4O_2$, m.p. 159°. *Acetate*, from ethyl acetate or acetone in brilliant, slender needles, m.p. 149°. *Benzoate*, ex ethyl acetate in silky needles, m.p. 164°.	(1) 1-Nitro-6 : 8(?)-dibromo-2-naphthol, compact, canary-yellow needles from benzene; on heating becomes orange at 155–160°, and melts and decomposes at 183°. (2) 6 : 8-Dibromo-1 : 2-naphthaquinone, orange-red, efflorescent needles from benzene, large prisms from ethyl acetate, m.p. 168°.	On oxidation both the naphthol and the derived quinone yield a new *dibromophthalic* acid, m.p. 195–196°; *anhydride*, m.p. 147·5°.
No. 3.  Ex tetrabromo β-naphthol No. 1 and boiling iodhydric acid.	From glacial acetic acid in flat, *efflorescent* needles (with 1 mol. $C_2H_4O_2$); melts at [illegible]°. *Acetate*, from ethylic acetate in slender lustrous needles, m.p. 147°.		Does not etherify when heated with alcohol and H_2SO_4 at 100°.

Isomeric Bromo-β-Naphthols—continued.

Bromo-derivative	Properties	Convertible by HNO_3 into	Remarks
No. 4.  Ex tetrabromo-β-naphthol No. 2 and boiling iodhydric acid.	From acetic acid in flat, *efflorescent* needles (with 1 mol. $C_2H_4O_2$); melts at 185–186°. *Acetate*, small leaflets ex ethyl acetate, m.p. 147°.		Does not etherify. Note close resemblance of naphthols 3 and 4 and acetates 2, 3, and 4.
Tetrabromo-β-naphthols. *No. 1.*  Ex β-naphthol in glacial acetic acid and excess of Br_2 in presence of iron.	From acetic acid in small balls of needles (*efflorescent*), m.p. 172°. *Acetate*, from ethylic acetate in long, lustreless prisms, or small six-sided plates, m.p. 192–193°.	(1) 1 - Nitro - 3 : 4 : 6-tribromo-β-naphthol, dark yellow needles, m.p. between 135–143°, depending on rate of heating. (2) 3 : 4 : 6 - tribromo - 1 : 2 - naphthaquinone, from ethylic acetate in large, deep-red nearly black rhombs, m.p. 190°.	Oxidation by dilute HNO_3 converts the naphthol and the derived quinone into 4-bromophthalic acid; anhydride, m.p. 106°.
No. 2.  By excess of Br_2 on *dry* β-naphthol at 100° in presence of iron.	From acetic acid or chloroform in long slender needles (*non-efflorescent*), m.p. 184°. *Acetate*, from ethylic acetate or acetone in small dumbbell-like aggregates of needles, m.p. 155°.	(1) Nitro-tribromo-β-naphthol, yellow tufts from alcohol, m.p. 156° (decomposes). (2) Tribromo - β -naphthaquinone from ethylic acetate in large red prisms, m.p. 183°.	Oxidation of either naphthol or quinone gives a new dibromophthalic acid, m.p. 195–196°; *anhydride*, m.p. 147·5°.
No. 3. Formed along with 1 and 2 in small quantity.	Small, colourless needles from acetic acid, m.p. 191°. *Acetate*, from acetic acid (very sparingly soluble) in felted mass of needles, m.p. 210°.	Does not yield a keto-compound initially with HNO_3, but gives immediately a tetrabromo - β - naphthaquinone, m.p. 241° (small red needles).	Attempts at oxidation hitherto unsuccessful.
Pentabromo-β-naphthols. *No. 1.* By action of bromine in excess on dry β-naphthol in presence of Al or Fe; also by bromine on tetrabromo, No. 2.	Tiny colourless needles from nitrobenzene, m.p. 241°. *Acetate*, ex ethylic acetate, small needles, m.p. 209°.	A tetrabromo-β-naphthaquinone, m.p. 164°.	On oxidation yields a tribromophthalic acid.[1]
No. 2. Ex tetrabromo-β-naphthol, No. 1, by dropping into bromine containing Al.	*Acetate*, m.p. 203°, white granules.		

[1] Flessa, *Ber.*, 17, 1479.

Bibliography of Spectroscopy.—Report of the Committee, consisting of Professor H. McLeod (*Chairman*), Sir W. C. Roberts-Austen (*Secretary*), Mr. H. G. Madan, *and* Mr. D. H. Nagel.

The Committee beg to present herewith the last instalment of the list of spectroscopic papers, continued until the end of the year 1900; it is unnecessary to continue it farther, as the work will now come into the hands of the compilers of the International Catalogue of Scientific Papers.

In the first report, presented in 1881, will be found a list of periodicals from which titles have been taken, but as in recent years the work has been entirely in the hands of only two members of the Committee, it was found impossible to look through all the periodicals mentioned in that list. The serials that have been recently examined are the following:—'Philosophical Transactions,' 'Proceedings of the Royal Society,' 'Journal of the Chemical Society,' 'Berichte der deutschen chemischen Gesellschaft,' 'Chemisches Centralblatt,' 'Proceedings of the Physical Society,' 'Science Abstracts,' 'Beiblätter,' 'Nature,' and 'Chemical News.' The abstracts and notices contained in these periodicals have been verified by reference to the original papers, and it is hoped that all the most important contributions to the knowledge of spectroscopy have been included in the list.

PAPERS ON SUBJECTS CONNECTED WITH SPECTROSCOPY.

The previous instalments of this catalogue will be found in the Reports of the Association for 1881, pp. 328–422; 1884, pp. 295–350; 1889, pp. 344–422; 1894, pp. 161–236; 1898, pp. 439–519.

[In cases where it has not been found possible to verify a reference, the latter is placed in brackets, in the same column as the title of the paper. A list of the chief abbreviations used will be found at the end of the catalogue.]

I.

INSTRUMENTAL.

1897.

J. Melander	Sur un prisme à angle variable. (Read Dec. 13.)	'Oefvers. af Finska Vet. Soc. Förhandl.' xl. 33–35; 'Beiblätter,' xxii. 555 (Abs.)
M. Hamy	Sur un appareil permettant de séparer des radiations simples très voisines. (Read Dec. 20.)	'C. R.' cxxv. 1092–1094.
J. Melander	Ein Spectrometer zur directen Unterscheidung der tellurischen Linien im Sonnenspectrum ('Finska Vet. Soc. Förh.' xxxix. 247–255).	'Beiblätter,' xxiii. 178–179 (Abs.)

1898.

H. Krüss	Spectro-photometer mit Lummer-Brodhun'schen Prismenpaar. (Jan.)	'Zeitschr. f. Instrumentenkunde,' xviii. 12–18; 'Beiblätter,' xxii. 839 (Abs.)

INSTRUMENTAL, 1898.

C. Fabry and A. Perot.	Sur un spectroscope interférentiel. (Read Jan. 24.)	'C. R.' cxxvi. 331–333; 'Nature,' lvii. 325 (Abs.); 'Science Abstr.' i. 247; 'Chem. News,' lxxvii. 82–83 (Abs.)
L. M. Dennis.	Eine neue Form des Entladers für Funkenspectren in Lösungen. (Jan.)	'Zeitschr. f. anorg. Chem.' xvi. 19–21; 'Beiblätter,' xxii. 218 (Abs.); 'Chem. Centr.' 1898, I. 428 (Abs.); 'J. Chem. Soc.' lxxiv. II. 185 (Abs.)
H. C. Vogel	Einige Bemerkungen über den Kirchhoff'schen Spectralapparat. (Read Feb. 17.)	'Sitzungsb. Akad. Berlin,' 1898, 141–147; 'Nature,' lviii. 19–20 (Abs.)
A. A. Michelson	A Spectroscope without Prisms or Gratings. (March.)	'Amer. J. Sci.' [4], v. 215–217; 'Beibl[illegible],' xxiii. 555–557 (Ab[illegible] 'Science Abstr.' i. 38[illegible] 'Nature,' lvii. 500 (Ab[illegible]
W. Hemmelmann	Verbessertes Absorptionsfläschchen für Spectralanalyse. (April.)	'Chem. Zeit[illegible]g,' xxii. 297–298; 'Chem. Centr.' 1898, I. 1063 (Abs.)
C. Zeiss .	Neue Construction des symmetrischen Doppelspaltes nach v. Vierordt. (April.)	'Zeitschr. f. Instrumentenkunde,' xviii. 116–117.
C. Pulfrich	Ueber einige Neueinrichtungen an dem Doppleprisma des Abbe'schen Refractometers, und über die von der Firma Zeiss hergestellten Refractometer dieser Art. (April.)	'Zeitschr. f. Instrumentenkunde.' xviii. 107–116; 'Beiblätter,' xxii. 661 (Abs.); 'Science Abstr.' i. 536.
A. Jobin . . .	Spectroscope interférentiel de MM. A. Perot et Ch. Fabry. (Read May 20.)	'Séances de la Soc. Franç. de Phys.' 1898, 46*–49*.
A. A. Michelson	The 'Echelon' Spectroscope. (June.)	'Astrophys. J.' viii. 37–47; 'Nature,' lviii. 280 (Abs.); 'Science Abstr.' i. 589–592.
C. Zeiss .	Spectralapparat nach E. A. Wülfing zur Beleuchtung mit Licht verschiedener Wellenlänge. (July.)	'Zeitschr. f. Instrumentenkunde,' xviii. 209–213.
F. Pfuhl . .	Ein einfacher Apparat zur Demonstration des Brechungsgesetzes der Lichtstrahlen. (July.)	'Zeitschr. f. phys. u. chem. Unterr.' xi. 159–161.
C. R. Mann	The Echelon Spectroscope. (Aug.)	'Science,' viii. 208–210.
H. Olsen	Ueber einen Gitterspectralapparat. (Sept.)	'Zeitschr. f. Instrumentenkunde,' xviii. 280–283; 'Beiblätter,' xxiii. 567 (Abs.)
W. A. Adeney and J. Carson.	On the Mounting of the large Rowland Spectrometer in the Royal University of Ireland. (Sept.)	'Proc. Roy. Soc. Dublin' [N.S.], viii. 711–716; 'Phil. Mag.' [5], xlvi. 223–227; 'Science Abstr.' ii. 98 (Abs.)

INSTRUMENTAL, 1898, 1899.

W. W. Campbell	The Mills Spectrograph of the Lick Observatory. (Oct.)	'Astrophys. J.' viii. 123–158; 'Science Abstr.' ii. 91 (Abs.)
R. Straubel	Ein Beleuchtungs apparat für monochromatisches Licht mit festen Spalten. (Oct.)	'Ann. Phys. u. Chem.' [N.F.], lxvi. 350–352; 'Science Abstr.' ii. 97 (Abs.)
C. Zeiss . . .	Ueber Quarzspectrographen und neuere spectrographische Hülfsapparate. (Nov.)	'Zeitschr. f. Instrumentenkunde,' xviii. 325–331; 'Beiblätter' xxiii. 249 (Abs.); 'Science Abstr. ii. 346.
Pulfrich	Ueber ein Vergleichspectroscop für Laboratoriumszwecke. (Dec.)	'Zeitschr. f. Instrumentenkunde,' xviii. 381–383; 'Beiblätter,' xxiii. 249–250 (Abs.)
C. Zeiss .	Totalrefractometer (Krystalrefractometer) nach E. Abbe.	'Neues Jahrb. f. Min. Geol. u. Paläont.' 1898, II. 65–67.
	Verbindung eines Dichroscopes mit einem Spectroscop.	'Neues Jahrb. f. Min. Geol. u. Paläont.' 1898, II. 68–69.
V. Schumann.	Von den brechbarsten Strahlen und ihrer photographischen Aufnahme.	'Jahrb. f. Photog.' xii. 20–22; 'Beiblätter,' xxii. 841 (Abs.)
E. A. Wülfing	Ueber einen Spectralapparat zur Herstellung von intensivem monochromatischem Licht.	'Neues Jahrb f. Mineral.' Beilage-Band xii. 343–404; 'Beiblätter' xxiii. 355–356 (Abs.)
	1899.	
J. H. White	Simplified Apparatus for Spectroscopic Photography. (Jan.)	'Scientific American,' lxxx. 43; 'Science Abstr.' ii. 739.
Sir J. N. Lockyer	A simple Spectroscope and its Teachings. (Lecture, Feb. 16.)	'Nature,' lix. 371–373, 391–393; 'Zeitschr. f. phys. u. chem. Unterr.' xii. 157–158; 'Beiblätter,' xxiii. 554–555 (Abs.)
C Zeiss .	Neues Refractometer mit Erhitzungseinrichtung nach Eykman. (March.)	'Zeitschr. f. Instrumentenkunde,' xix. 65–74; 'Beiblätter,' xxiii. 767 (Abs.)
H. Starke	Ein Refractometer zur Bestimmung des Brechungsexponenten von Flüssigkeiten mit dem Microscop. (Read April 7.)	'Verh. Deutsch. phys. Gesellsch.' i. 117–122; 'Science Abstr.' ii. 596; 'Beiblätter,' xxiv. 27–29 (Abs.)
	On the Use of Photographic Films in Astronomical Photography. (April.)	'Nature,' lix. 614.
C. P. Butler .	The Michelson Echelon Spectroscope. (April.)	'Nature,' lix. 607–609.
C. S. Hastings	A new Type of Telescopic Objective specially adapted for Spectroscopic Use. (April.)	'Amer. J. Sci.' vii. [4], 267–270; 'Nature,' lix. 621 (Abs.); 'Science Abstr.' ii. 660.

INSTRUMENTAL, 1899, 1900.

A. A. Michelson	On the Echelon Spectroscope. (Read June 5.)	'Trans. Phil. Soc. Cambridge,' xviii. 316–323.
A. de Gramont	Sur un spectroscope de laboratoire à dispersion et à échelle réglables. (Read June 26.)	'C. R.' cxxviii. 1564–1568; 'Beiblätter,' xxiv. 178 (Abs.); 'Science Abstr.' ii. 739.
S. A. Mitchell	The direct Concave Grating Spectroscope. (June.)	'Astrophys. J.' x. 29–39; 'Nature,' lx. 302 (Abs.); 'Science Abstr.' ii. 824.
Ph. Pellin and A.	Spectroscope à déviation fixe. (June.)	'J. de Phys.' [3], viii. 314–319; 'Astrophys. J.' x. 337–342; 'Beiblätter,' xxiv. 462 (Abs.); 'Science Abstr.' ii. 663.
A. A. Michelson	The Echelon Spectroscope. (Oct.)	'Proc. Amer. Acad.' xxxv. 111–119; 'J. de Phys.' [3], viii. 305–314; 'Beiblätter,' xxiv. 457–458 (Abs.)
D. P. Brace	On a new Spectrophotometer and an Optical Method of Calibration. (Nov.)	'Phil. Mag.' [5] xlviii. 420–430; 'Beiblätter,' xxiv. 458–459 (Abs.); 'Science Abstr.' iii. 14–15.
G. E. Hale	Some new Forms of Spectroheliographs. (Nov.)	'Astrophys. J.' x. 288–290.
C. Pulfrich	Ueber ein neues Refractometer mit veränderlichen brechenden Winkel. (Nov.)	'Zeitschr. f. Instrumentenkunde,' xix. 335–339.
F. F. Martens	Ueber eine Neuconstruction des König'schen Spectralphotometer. (Read Dec. 15.)	'Verhandl. Deutsch. Phys. Gesellsch.' i. 280–284; 'Beiblätter,' xxiv. 466 (Abs.)
W. H. Perkin	An improved Spectrometer Scale Reader. (Read Dec. 21.)	'J. Chem. Soc.' lxxvii. 267–294; 'Beiblätter,' xxiv. 929–930 (Abs.)
E. Beckmann	Ueber die Erzeugung leuchtender Flammen zu spectroscopischen Zwecken mit Hilfe der Electrolyse. (Zeitschr. f. Electrochem. v. 327.)	'Beiblätter,' xxiii. 778 (Abs.)
L. Levy	Das Interferenzspectrometer von Ch. Fabry und A. Perot ('Der Mechaniker,' vii. 111–113.)	'Beiblätter,' xxiii. 773 (Abs.)
A. A. Michelson	Sur le spectroscope à échelons.	'J. de Phys.' [3], viii. 305–314; 'Science Abstr.' ii. 740.
F. Wallerant	Perfectionnement au réfractomètre pour les cristaux microscopiques.	'Bull. Soc. Min. de Paris,' xxii. 67–69.

1900.

D. P. Brace	On a new System for Spectral Photometric Work. (Jan.)	'Astrophys. J.' xi. 6–24; 'Beiblätter,' xxiv. 779–780 (Abs.)

INSTRUMENTAL, 1900.

E. V. Capps	Calibration of the Slit in Spectral Photometric Measurements. (Jan.)	'Astrophys. J.' xi. 25–35; 'Science Abstr.' iii. 302; 'Beiblätter,' xxiv. 777 (Abs.)
F. F. Martens	Ein Colorimeter als Zusetzapparat für Spectroscope mit Wellenlängescala. (Jan.)	'Phys. Zeitschr.' i. 182–183; 'Beiblätter,' xxiv. 465 (Abs.); 'Science Abstr.' iii. 627.
C. Fabry and A. Perot	Nouvelle source de lumière pour la spectrométrie de précision. (Read Feb. 12.)	'C.R.' cxxx. 406–409; 'Beiblätter,' xxiv. 256 (Abs.); 'Science Abstr.' iii. 376.
J. Hartmann.	Bemerkungen über den Bau und die Justirung von Spectrographen. (Feb.)	'Zeitschr. f. Instrumentenkunde,' xx. 17–27, 47–58; 'Beiblätter,' xxiv. 459–461 (Abs.); 'Astrophys. J.' xi. 400–413.
C. J. Abbot and F. E. Fowle	A Prism of Universal Dispersion. (March.)	'Astrophys. J.' xi. 135–139; 'Nature,' lxi. 597 (Abs.); 'Beiblätter,' xxiv. 993 (Abs.)
W. S. Adams	The Curvature of the Spectral Lines in the Spectroheliograph. (May.)	'Astrophys. J.' xi. 309–311; 'Science Abstr.' iii. 688.
W. W. Campbell	The Temperature Control of the Mills Spectrograph. (May.)	J.' xi. 259–261; 'Nature,' lxii. 137 (Abs.); 'Science Abstr.' iii. 687.
G. B. Rizzo	Una vantaggiosa disposizione sperimentale per lo studio degli spettri di diffrazione dei reticoli concavi. (Read June 18.)	'Atti R. Accad. Torino, xxiv. 794–799; 'Mem. Soc. Spettr. Ital.' xxviii. 241–244; 'Beiblätter,' xxiv. 462–463 (Abs.); 'Nature,' lxi. 561–562 (Abs.)
E. Beckmann	Ueber Spectrallampen, I. (June.)	'Zeitschr. f. physikal. Chem.' xxxiv. 593–611; 'Chem. Centr.' 1900. II. 801 (Abs.); 'Beiblätter,' xxiv. 1282 (Abs.); 'J. Chem. Soc.' lxxviii. II. 701–702 (Abs.)
H. C. Vogel	Description of the Spectrographs for the great Refractor at Potsdam. (June.)	'Astrophys. J.' xi. 393–399; 'Nature,' lxii. 459 (Abs.)
C. Fabry and A. Perot	Sur les sources de lumière monochromatique. (July.)	'J. de Phys.' [3], ix. 369–382; 'Nature,' lxii. 350 (Abs.)
J. Hartmann.	Remarks on the Construction and Adjustment of Spectrographs. II. (July.)	'Astrophys. J.' xii. 30–47
H. Lehmann	Ueber Spectralapparate mit drehbarem Gitter. (July.)	'Zeitschr. f. Instrumentenkunde,' xx. 193–204; 'Beiblätter,' xxiv. 1115–1116 (Abs.)

F. Paschen	Ein Geissler'sche Röhre mit Quecksilber Electroden zum Studium des Zeemaneffectes. (Aug.)	'Phys. Zeitschr.' i. 478–480.
C. Fritsch	Eine neue Spaltvorrichtung an Spectralapparaten. (Sept.)	'Phys. Zeitschr.' i. 543–544; 'Beiblätter,' xxiv. 1117–1118 (Abs.); 'Science Abstr.' iv. 26.
C. Pulfrich	Vergleichsspectroscope für Farbentechniker. (Oct.)	'Zeitschr. f. Instrumentenkunde,' xx. 299–301; 'Beiblätter,' xxiv. 1277 (Abs.)
E. Beckmann	Ueber Spectrallampen. II. (Nov.)	'Zeitschr. f. physikal. Chem.' xxxv. 443–458; 'Chem. Centr.' 1901, I. 1 (Abs.); 'Beiblätter,' xxv. 37 (Abs.)
W. H. Wright	The Auxiliary Apparatus of the Mills Spectrograph for Photographing the Comparison Spectrum. (Nov.)	'Astrophys. J.' xii. 274–278; 'Beiblätter,' xxv. 39–40 (Abs.)
E. Beckmann	Ueber Spectrallampen. III. (Dec.)	'Zeitschr. f. physikal. Chem.' xxxv. 652–660; 'Beiblätter,' xxv. 129–130 (Abs.); 'J. Chem. Soc.' lxxx. II. 81 (Abs.)
O. Lummer	Ueber neuere Interferenzrefractometer. ('Der Mechaniker,' viii. 25–28, 37–40.)	'Beiblätter,' xxiv. [37] (title).

II.

EMISSION SPECTRA.

1897.

M. W. Travers	Some Experiments on Helium. (Read Feb. 4.)	'Proc. Roy. Soc.' lx. 449–453; 'J. Chem. Soc.' lxxiv. II. 375–376 (Abs.)
O. Lohse	Untersuchung des violetten Theiles einiger linienreicher Metallspectren. (Read March 4.)	'Sitzungsb. Akad. Berlin,' 1897, 179–197.
W. N. Hartley	Experiments on the Flame Spectrum of Carbonic Oxide. (Read Mar. 18.)	'Proc. Roy. Soc.' lxi. 217–219; 'J. Chem. Soc.' lxxiv. II. 361–362 (Abs.)
F. Exner and E. Haschek.	Ueber die ultravioletten Funkenspectra der Elemente. VIII. (Read May 13.)	'Sitzungsb. Akad. Wien,' cvi. II.a, 337–356; 'Science Abstr.' i. 195.
G. B. Rizzo	Ricerche spettroscopiche sull' argon. (Read May 23.)	'Atti R. Accad. Torino,' xxxii. 570–579; 'Beiblätter,' xxii. 666 (Abs.)
Lecoq de Boisbaudran.	Examen de quelques spectres. (Read June 8 and 21.)	'C. R.' cxxiv. 1288–1290, 1419–1421; 'Chem. News,' lxxvi. 46–47 (Abs.)
F. Exner and E. Haschek.	Ueber die ultravioletten Funkenspectra der Elemente. IX. (Read July 8.)	'Sitzungsb. Akad. Wien,' cvi. II.a, 494–520; 'Science Abstr.' i. 248.

EMISSION SPECTRA, 1897, 1898.

A. de Gramont .	Sur le spectre du carbone. (Read July 19.)	'C. R.' cxxv. 172–175.
" .	Sur le spectre des lignes du carbone dans les sels fondus. (Read July 26.)	'C. R.' cxxv. 238–240.
H. L. Callendar and N. N. Evans.	The Behaviour of Argon in X-ray Tubes (Aug.)	'Nature,' lvi. 624–625; 'Brit. Assoc. Rep.' 1897, 553 (Abs.)
A. L. Foley . .	Arc Spectra. (Sept.)	'Phys. Review,' v. 129–151; 'Science Abstr.' i. 55.
H. Konen . .	Ueber die Spectren des Jod. (Bonn Dissertation, Oct. 1897.)	'Ann. Phys. u. Chem.' [N.F.], lxv. 257–286; 'J. Chem. Soc.' lxxiv. II. 493 (Abs.); 'Nature,' lviii. 335 (Abs.)
B. Hasselberg .	Untersuchungen über die Spectra der Metalle im electrischen Flammenbogen. IV. Spectrum des Mangans. (Read Nov. 10.)	'Handl. k. Svensk. Vet. Akad.' xxx. 20 pp.
J. R. Rydberg .	The New Series in the Red Spectrum of Hydrogen. (Nov.)	'Astrophys. J.' vi. 233–238; 'Nature,' lvii. 157 (Abs.)
S. Försling . .	Om Praseodidymens spectra. (Read Dec. 8.)	'Bihang till K. Vet. Akad. Handl.' xxiii. Afd. i. No. 5, 20 pp.; 'Beiblätter,' xxiii. 484 (Abs.)
F. Exner and E. Haschek.	Ueber die ultravioletten Funkenspectra der Elemente. X. (Read Dec. 16.)	'Sitzungsb. Akad. Wien,' cvi. II.a, 1127–1152.
H. Wilde . .	On New Spectral Lines of Oxygen. (Dec.)	'Chem. News,' lxxvi. 288.
E. Rancken . .	Untersuchung über das Linienspectrum des Schwefels. (Dissert. Helsingfors, 52 pp.)	'Zeitschr. f. anorg. Chem.' xviii. 86 (Abs.); 'Chem. Centr.' 1898, II. 1004 (Abs.); 'Beiblätter,' xxiii. 96–97 (Abs.)

1898.

J. M. Eder and E. Valenta.	Das Linien-spectrum des Siliciums. (Read Jan. 13.)	'Sitzungsb. Akad. Wien,' cvii. II.a, 41–43; 'Beiblätter,' xxii. 774 (Abs.); 'Chem. Centr.' 1898, I. 1095 (Abs.); 'Chem. News,' lxxvii. 206.
Birkeland . .	Sur le spectre des rayons cathodiques. (Read Jan. 17.)	'C. R.' cxxvi. 228–231; 'Beiblätter,' xxii. 174–175 (Abs.)
M. Hamy . .	Sur le spectre du cadmium dans un tube à vide. (Read Jan. 17.)	'C. R.' cxxvi. 231–234; 'Beiblätter,' xxii. 153 (Abs.); 'Chem. News,' lxxvii. 71 (Abs.); 'J. Chem. Soc.' lxxiv. II. 321 (Abs.)

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A. Perot and C. Fabry.	Étude de quelques radiations par la spectroscopie interférentielle. (Read Jan. 31.)	'C. R.' cxxvi. 407–410; 'Nature,' lvii. 359 (Abs.); 'Science Abstr.' i. 247; 'Beiblätter,' xxiii. 29–30 (Abs.)
F. Exner and E. Haschek.	Ueber die ultravioletten Funkenspectra der Elemente. XI., XII., XIII., XIV. Mitth. (Read Feb. 10, July 7, Dec. 15.)	'Sitzungsb. Akad. Wien,' cvii. 102–206, 792–812, 813–837, 1335–1380; 'Wien. Anz.' 1898, 182 (Abs.)
A. Schuster	Profs. C. Runge and F. Paschen's Researches on the Spectra of Oxygen, Sulphur, and Selenium. (Feb.)	'Nature,' lvii. 320–321.
H. Kayser	On the Arc Spectra of the Platinum Group. I., II. (Feb.)	'Astrophys. J.' vii. 93–113, 173–197.
H. Rubens and E. Aschkinass.	Beobachtungen über Absorption und Emission von Wasserstoff und Kohlensäure im ultraroten Spectrum. (March.)	'Ann. Phys. u. Chem.' [N.F.] lxiv. 584–601.
E. Demarçay	Sur le spectre et la nature du néodyme. (Read April 4.)	'C. R.' cxxvi. 1039–1041; 'Chem. Centr.' 1898, I. 101 (Abs.)
G. C. Schmidt	Sur les radiations émises par le thorium et ses composés. (Read April 23.)	'C. R.' cxxvi. 1264.
H. A. Rowland and C. N. Harrison.	The Arc-spectrum of Vanadium. (April.)	'Astrophys. J.' vii. 273–294; 'Beiblätter,' xxii. 841–842 (Abs.)
	Arc-spectra of Zirconium and Lanthanum. (May.)	'Astrophys. J.' vii. 373–389.
W. Ramsay and M. W. Travers.	On a new Constituent of Atmospheric Air. (Read June 9.)	'Proc. Roy. Soc.' lxiii. 405–408; 'Chem. News,' lxxvii. 287; 'Nature,' lviii. 127–128.
H. Moissan and H. Deslandres.	Recherches spectrales sur l'air atmosphérique. (Sealed packet deposited May 11, 1896; opened and read June 13, 1898.)	'C. R.' cxxvi. 1689–1691; 'Chem. Centr.' 1898, II. 82 (Abs.); 'Chem. News,' lxxvii. 288.
C. Fabry and A. Perot.	Sur l'étude des radiations du mercure, et la mesure de leurs longueurs d'onde. (Read June 13.)	'C. R.' cxxvi. 1706–1708; 'Science Abstr.' i. 640; 'Beiblätter,' xxiii. 781 (Abs.)
W. Ramsay and M. W. Travers.	On the Companions of Argon. (Read June 16.)	'Proc. Roy. Soc.' lxiii. 437, 440; 'Chem. News,' lxxviii. 1–2; 'Nature,' lviii. 182–183.
T. N. Thiele	Resolution into Series of the Third Band of the Carbon Band Spectrum.	'Astrophys. J.' viii. 1–27; 'Beiblätter,' xxiii. 357 (Abs.)

EMISSION SPECTRA, 1898.

E. Jewell	The structure of the shading of the H and K and some other lines in the spectrum of the sun and arc.	'Johns Hopkins Univ. Circ.' xvii. 62–63; 'Astrophys. J.' viii. 51–53; 'Beiblätter,' xxiii. 359–360 (Abs.); 'Nature,' lviii. 280 (Abs.)
J. M. Eder and E. Valenta.	Spectralanalyse der Leuchtgasflamme. (Read July 7.)	'Denkschr. Akad. Wien,' lxvii. 12 pp.; 'Beiblätter,' xxiii. 251–252 (Abs.)
	Ueber das Funkenspectrum des Calciums und des Lithiums, und seine Verbreiterungs und Umkehrungserscheinungen. (Read July 7.)	'Denkschr. Akad. Wien,' lxvii. 11 pp.; 'Chem. Centr.' 1898, II. 1118 (Abs.); 'Beiblätter,' xxiii. 250–251 (Abs.)
A. Schuster	The Spectrum of Metargon. (July.)	'Nature,' lviii. 199, 269–270; 'Beiblätter,' xxii. 513–514, 772–773 (Abs.)
. Ramsay, M. W. Travers, and E. C. C. Baly.	The Spectrum of Metargon. (July.)	'Nature,' lviii. 245–246; 'Beiblätter,' xxii. 772–773 (Abs.)
. Nasini. F. Anderlini, and R. Salvadori.	Terrestrial Coronium. (July.)	'Chem. News,' lxxviii. 43 (from the 'Times' of July 20); 'Beiblätter,' xxii. 842 (Abs.)
. Kalähne	Ueber die Spectra einiger Elemente bei der stetigen Glimmentladung in Geissler'schen Röhren, und die Abhängigkeit der Lichtstrahlung von Stromstärke und Druck. (July.)	'Ann. Phys. u. Chem.' [N.F.], lxv. 815–848; 'J. Chem. Soc.' lxxiv. II. 549 (Abs.); 'Science Abstr.' ii. 14.
Dewar	Metargon. (Aug.)	'Nature,' lviii. 319.
. S. Hutton	The Compound Line Spectrum of Hydrogen. (Sept.)	'Phil. Mag.' [5], xlvi. 338–343; 'J. Chem. Soc.' lxxvi. II. 3 (Abs.); 'Chem. Centr.' 1899, I. 12 (Abs.)
. Erdmann	Ueber die farbige Abbildung der Emissionsspectra. (Sept.)	'Naturw. Rundschau,' xiii. 465–467.
. C. C. Baly	Helium in the Atmosphere. (Sept.)	'Nature,' lviii. 545.
r W. Crookes	Helium in the Atmosphere. (Oct.)	'Nature, lviii. 570; 'Chem. News,' lxxviii. 198–199.
M. Eder and E. Valenta.	Ueber das rothe Spectrum des Argons. (Read Oct. 24.)	'Monatsh. f. Chem.' xvi. 893–895; 'J. Chem. Soc.' lxxiv. II. 2–4 (Abs.)
	Vorläufige Mittheilung über das Spectrum des Chlors. (Read Nov. 17.)	'Wien. Anz.' 1898, 252–255.
. D. Liveing	On the Flame-spectrum of Mercury, and its bearing on the Distribution of Energy in Gases. (Read Nov. 28.)	'Proc. Phil. Soc. Cambridge,' x. 38–48; 'Beiblätter,' xxiii. 781 (Abs.); 'Nature,' lix. 142 (Abs.)
'. Ramsay	The Spectrum of Krypt	Nature,' lix. 53.

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EMISSION SPECTRA, 1898, 1899.

J. Trowbridge . .	Some Results obtained with a Storage Battery of Twenty Thousand Cells. (Address at a meeting of the Amer. Acad. Dec. 14.)	'Proc. Phys. Soc.' xvii. 651–663; 'Nature,' lxii. 325–327.
E. Demarçay . .	Sur le spectre d'une substance radio-active. (Read Dec. 26.)	'C. R.' cxxvii. 1218; 'Chem. Centr.' 1900, I. 4 (Abs.); 'J. Chem. Soc.' lxxviii. II. 83 (Abs.); 'Chem. News,' lxxix. 13.
P. Curie, Mme. Curie, and G. Bémont . .	Sur une nouvelle substance fortement radio-active contenue dans la pechblende. (Read Dec. 26.)	'C. R.' cxxvii. 1215–1217; 'Chem. News,' lxxix. 1–2; 'Nature,' lix. 232 (Abs.); 'Science Abstr.' ii. 280.
E. S. Ferry . .	A Photometric Study of the Spectra of Mixtures of Gases at Low Pressures. (Dec.)	'Phys. Review,' vii. 296–306; 'Beiblätter,' xxiii. 251 (Abs.)
J. M. Eder and E. Valenta.	Die Spectren des Schwefels. ('Denkschr. Akad. Wien,' lxvii. 97–151.)	'Beiblätter,' xxii 773 (Abs.)

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Mme. S. Curie .	Les rayons de Becquerel et le Polonium. (Jan.)	'Rev. gén. des Sciences,' x. 11–50; 'Chem. News lxxix. 77–78 (Abs.)
A. Schuster and G. Hemsalech.	The Constitution of the Electric Spark. (Read Feb. 2.)	'Proc. Roy. Soc.' lxiv 331–336; 'Nature,' lix 350–352; 'Chem. News, lxxix. 62–64.
J. W. Richards .	Note on the Spectra of Hydrogen. (Feb.)	'Amer. Chem. J.' xxi. 172–174; 'Chem. Centr.' 1899, I. 659 (Abs.); 'J. Chem. Soc.' lxxvi. II. 266 (Abs.); 'Chem. News,' lxxix. 159–160.
J. M. Eder and E. Valenta.	Das Spectrum des Chlors. (Read April 13.)	'Denkschr. Akad. Wien,' lxviii. 437–447.
L. E. Jewell	Notes on the Papers of Hartley and Ramage concerning the Spectrum of Gallium and the Spectra of Meteorites. (April.)	'Astrophys. J.' ix. 229–230; 'Beiblätter,' xxiii. 789 (Abs.)
C. Fabry and A. Perot.	Sur une source intense de lumière monochromatique. (Read May 8.)	'C. R.' cxxviii. 1156–1158; 'J. Chem. Soc.' lxxvi. II. 261 (Abs.); 'Science Abstr.' ii. 659.
A. Perot and C. Fabry.	Sur l'alimentation des tubes de M. Michelson par diverses sources électriques. (Read May 15.)	'C. R.' cxxviii. 1221–1223; 'Science Abstr.' ii. 508.
C. Runge	On the Red End of the Red Argon Spectrum. (May.)	'Astrophys. J.' ix. 281–283; 'Science Abstr.' ii. 823; 'Beiblätter,' xxiii. 780 (Abs.)
W. W. Campbell	A Comparison of the Visual Hydrogen Spectra of the Orion Nebula and of a Geissler Tube. (May.)	'Astrophys. J.' ix. 312–316; 'Beiblätter,' xxiii. 793–794 (Abs.)

EMISSION SPECTRA, 1899.

Exner and E. Haschek.	Ueber die ultravioletten Funkenspectra der Elemente., XV. (Read June 15.)	'Sitzungsb. Akad. Wien.' cviii. II.a, 825–859; 'Beiblätter,' xxiv. 109–110 (Abs.)
	Ueber die ultravioletten Funkenspectra der Elemente. XVI. XVII. (Read June 15.)	'Sitzungsb. Akad. Wien, cviii. II.a, 1071–1121, 1123–1151, 1252–1266; 'Science Abstr.' ii. 782–783.
J. M. Eder and E. Valenta.	Das Spectrum des Broms. (Read July 6.)	'Denkschr. Akad. Wien,' lxviii 523–530; 'Beiblätter,' xxiv. 260–262 (Abs.); 'J. Chem. Soc.' lxxviii. II. 330 (Abs.)
G. A. Hemsalech .	Sur les spectres des décharges oscillantes. (Read July 31.)	'C. R.' cxxix. 285–288; 'J. de Phys.' [3], viii. 652–660; 'Beiblätter,' xxiii. 1050–1051 (Abs.) 'Nature,' lx. 360 (Abs.) 'Science Abstr.' ii. 853.
C. Runge . .	The Spectra of Krypton. (Aug.)	'Astrophys. J.' x. 73–79; 'Beiblätter,' xxiv. 108–109 (Abs.); 'Science Abstr.' iii. 20.
E. P. Lewis . .	The Spectral Sensitiveness of Mercury in an Atmosphere of Hydrogen, and its influence on the spectrum of the latter. (Sept.)	'Brit. Assoc. Rep.' 1899, 660–661.
„ . .	Ueber den Einfluss kleiner Beimengungen zu einem Gase auf dessen Spectrum. (Oct.)	'Ann. Phys. u. Chem.' [N. F.], lxix. 398–425; 'J. Chem. Soc.' lxxviii. II. 1–2 (Abs.); 'Nature,' lxi. 93 (Abs.)
R. Nasini, F. Anderlini and R. Salvadori.	Sopra alcune righe non mai osservate nella regione ultrarossa dello spettro dell' argo. (Read Nov. 19.)	'Rend. R. Accad. d. Lincei' [5], viii. II. 269–271; 'Gazz. chim. Ital.' xxx. I. 189–191; 'J. Chem. Soc.' lxxviii. II. 181 (Abs.); 'Beiblätter,' xxiv. 259–260 (Abs.)
Sir J. N. Lockyer .	Note on the Spectrum of Silicium. (Read Nov. 23.)	'Proc. Roy. Soc.' lxv. 449–461; 'Nature,' lxi. 262–263; 'Beiblätter,' xxiv. 262 (Abs.)
A. Wüllner . .	Ueber die Spectra der Canalstrahlen und der Cathodenstrahlen. (Dec.)	'Phys. Zeitschr.' i. 132–134; 'Science Abstr.' ii. 531.
B. Hasselberg .	Untersuchungen über die Spectra der Metalle im electrischen Flammenbogen. V. Spectrum des Vanads. ('Handl. Svensk. Vet. Akad.' xxxii. No. 2, 32 pp.)	'Beiblätter,' xxiii. 634 (Abs.); 'Astrophys. J.' x. 343–361; 'Science Abstr.' iii. 308.
H. Lehmann .	Die ultraroten Spectren der Alkalien. ('Arch. f. Wiss. Photogr.' ii. 216–222.)	'Beiblätter,' xxv 27–28 (Abs.)

EMISSION SPECTRA, 1899, 1900.

L. Rummel	The Spectra of Oxygen, Sulphur, and Selenium. ('Trans. Roy. Soc. Victoria [2], xii. 14–17.)	'Beiblätter,' xxiv. 180 (Abs.)

1900.

R. Přibram	Ueber das Austrium. (Read Jan. 4.)	'Sitzungsb. Akad. Wien,' cix. II.a, 16–23; 'Monatsh.' f. Chem. xxi. 148–155; 'Chem. Centr.' 1900, I. 346 (Abs.); 'J. Chem. Soc.' lxxviii. II. 347–348 (Abs.)
F. Exner and E. Haschek.	Ueber die ultravioletten Funkenspectra der Elemente. XVIII. Mittheilung. [Skandium, Samarium, und Gadolinium.] (Read Feb. 1.)	'Sitzungsb. Akad. Wien,' cix. II.a, 103–169.
C. Fabry and A. Perot.	Sur la constitution des raies jaunes du sodium. (Read March 5.)	'C. R.' cxxx. 653–655; 'Beiblätter,' xxiv. 674 (Abs.); 'Nature,' lxi. 483 (Abs.); 'Science Abstr.' iii. 376.
A. Ladenberg and C. Krügel.	Ueber das Krypton. (Read March 22.)	'Sitzungsb. Akad. Berlin.' 1900, 212–217; 'Chem. Centr.' 1900, I. 945–946 (Abs.); 'Chem. News,' lxxxi. 205–207.
R. Hasselberg	Note sur les spectres des décharges oscillantes. (March.)	'J. de Phys.' [3], ix. 153–155; 'Beiblätter,' xxiv. 472 (Abs.)
E. Goldstein	Ueber Spectra von Gasgemengen und von Entladungshüllen. (Read May 11.)	'Verh. Deutsch. Phys. Gesellsch.' ii. 110–112.
V. Schumann	A second Spectrum of Hydrogen beyond $\lambda = 185\ \mu\mu$. (May.)	'Astrophys. J.' xi. 312–313; 'Beiblätter,' xxiv. 910 (Abs.)
W. Muthmann and E. Bauer.	Einige Beobachtungen über Luminescenzspectren. (Read June 5.)	'Ber.' xxxiii. 1748–1763; 'Chem. Centr.' 1900, II. 233–234 (Abs.); 'Beiblätter,' xxiv. 1126–1127 (Abs.)
C. C. Schenk	Some Properties of the Electric Spark and its Spectrum. (June.)	'Johns Hopkins Univ. Circ.' xix. 63–64.
W. B. Huff	The Spectra of Mercury. (June.)	'Johns Hopkins Univ. Circ.' xix. 62; 'Astrophys. J.' xii. 103–119; 'Beiblätter,' xxiv. 1293 (Abs.); 'Science Abstr.' iii. 950–951.
G. A. Hemsalech	Ueber das Bandenspectrum des Aluminiums. June.)	'Ann. der Phys.' [4], ii. 331–334; 'Science Abstr.' iii. 690; 'Nature,' lxii. 335 (Abs.); 'Chem. Centr.' 1900, II. 86 (Abs.)

EMISSION SPECTRA, 1900.

E. Demarçay	Sur le spectre du radium. (Read July 23.)	'C. R.' cxxxi. 258-259; 'Beiblätter,' xxiv. 1121 (Abs.); 'J. Chem. Soc. lxxviii. II. 586 (Abs.)
	Sur le gadolinium. (Read July 30.)	'C. R.' cxxxi. 343-345; 'Chem. Centr.' 1900, II. 557 (Abs.); 'Chem. News,' lxxxii. 97-98.
F. Exner and E. Haschek.	Note on the Spectrum of Silicon. (July.)	'Astrophys. J.' xii. 48-49; 'Science Abstr.' iii. 950.
E. Demarçay	Sur quelques nouveaux spectres des terres rares. (Read Aug. 6.)	'C. R.' cxxxi. 387-389; 'J. Chem. Soc.' lxxviii. II. 656 (Abs.); 'Science Abstr.' iii. 854; 'Chem. News,' lxxxii. 127.
C. J. Rollefson	Spectra of Mixtures. (Aug.)	'Phys. Review,' xi. 101-104.
C. Runge	Ueber das Spectrum des Radiums.	'Ann. der Phys.' [4], iii. 742-745; 'Nature,' lxii. 568 (Abs.); 'Science Abstr.' iii. 853-854.
J. Trowbridge	The Spectrum of Hydrogen and the Spectrum of Aqueous Vapour. (Sept.)	'Amer. J. Sci.' [4], x. 222-230; 'Nature,' lxii. 568 (Abs.); 'Phil. Mag.' [5], l. 338-347; 'J. Chem. Soc.' lxxviii. II. 701 (Abs.)
H. Crew	On the Arc Spectra of some Metals as influenced by an Atmosphere of Hydrogen. (Oct.)	'Phil. Mag.' [5], l. 497-505; 'Astrophys. J.' xii. 167-175; 'Nature,' lxiii. 114 (Abs.); 'Science Abstr.' iv. 24.
H. Kayser	Normalen aus dem Bogenspectrum des Eisens. (Oct.)	'Ann. der Phys.' [4], ii. 195-203.
Sir J. N. Lockyer	Note on the Spectrum of Silicium. (Read Nov. 2.)	'Proc. Roy. Soc.' lxvii. 402-409; 'Chem. Centr.' 1901, I. 436 (Abs.)
W. Ramsay and M. W. Travers.	Argon and its Companions. (Read Nov. 15.)	'Proc. Roy. Soc.' lxvii. 329-333 (Abs.)
E. Demarçay	Sur les spectres du samarium et du gadolinium. (Read Dec. 10.)	'C. R.' cxxxi. 995-998; 'Beiblätter,' xxv. 193-194 (Abs.); 'Chem. News,' lxxxiii. 11 (Abs.)
G. D. Liveing and J. Dewar.	On the Spectrum of the more Volatile Gases of Atmospheric Air, which are not condensed at the Temperature of Liquid Hydrogen. Preliminary Notice. (Read Dec. 13.)	'Proc. Roy. Soc.' lxvii. 467-474; 'Chem. News,' lxxxiii. 1-2, 13-15 'Nature,' lxiii. 189-190 (Abs.)
G. Berndt	Ueber die Spectra von Radium und Polonium. (Dec.)	'Physikal. Zeitschr.' ii. 180-181; 'Beiblätter,' xxv. 38-39 (Abs.); 'Chem. News,' lxxxiii. 77-78; 'Science Abstr.' iv. 225.

EMISSION SPECTRA, 1900—ABSORPTION SPECTRA, 1898.

W. N. Hartley	Spectrum of Cyanogen.	'Proc. Roy. Soc. Dublin,' ix. 289–297.
H. Lehmann .	Die ultraroten Spectren. (Freiburg i. B. Univ. Buchdr. Chr. Lehmann Nachf., 13 pp.)	'Beiblätter,' xxiv. 1119–1120 (notice.)

III.

ABSORPTION SPECTRA.

1894.

G. Krüss and E. Thiele.	Ueber die Lösungzustand des Jod, und die wahrscheinliche Ursache der Farbenunterschiede seiner Lösungen. (Jan.)	'Zeitschr. f. anorg. Chem.' vii. 52–81 ; 'J. Chem. Soc.' lxvi. II. 445–446 (Abs.)

1897.

G. Dimmer	Ueber die Absorptionsspectren von Didymsulfat und Neodymammonnitrat. (Read Dec. 16.)	'Sitzungsb. Akad. Wien.' cvi. II.a, 1087–1102.

1898.

D. F. Harris	Some Contributions to the Spectroscopy of Hæmoglobin and its Derivatives. (Read Feb. 7.)	'Proc. Roy. Soc. Edin.' xxii. 187–208.
W. N. Hartley and J. J. Dobbie .	The Ultra-violet Absorption Spectra of some Closed-chain Carbon Compounds. (Read Feb. 17.)	'J. Chem. Soc.' lxxiii. I., 598–606 ; 'Chem. News,' lxxvii. 103 (Abs.); 'Nature,' lvii. 430 (Abs.)
	Notes on the Absorption Bands in the Spectrum of Benzene. (Read Feb. 17.)	'J. Chem. Soc.' lxxiii. I. 695–697 ; 'Chem. Centr.' 1899, I. 198–199; 'Chem. News,' lxxvii. 103 (Abs.); 'Science Abstr.' ii. 739.
G. Urbain . .	Sur une nouvelle méthode de fractionnement des terres yttriques. (Read Mar. 14.)	'C. R.' cxxvi. 835–838; 'Chem. Centr.' 1898, I. 879 (Abs.); 'Chem. News,' lxxvii. 147–148 (Abs.)
O. Boudouard	Sur le néodyme. (Read Mar. 21.)	'C R.' cxxvi. 900–901; 'Chem. Centr.' 1898, I. 983 (Abs.); 'Chem. News,' lxxvii. 193.
C. A. Schunck	A Photographic Investigation of the Absorption Spectra of Chlorophyll and its Derivatives in the Violet and Ultra-violet Region of the Spectrum. (Read Mar. 24.)	'Proc. Roy. Soc.' lxiii. 389–396 ; 'J. Chem. Soc.' lxxvi. II. 540 (Abs.)
H. Rubens and E. Aschkinass .	Beobachtungen über Absorption und Emission von Wasserdampf und Kohlensäure im ultrarothen Spectrum. (March.)	'Ann. Phys. u. Chem. [N.F.], lxiv. 584–601; 'Nature,' lviii. 93 (Abs.)
V. Arnold	Ueber die Heller'sche Probe zum Nachweis des Blutfarbstoffes im Harn. (March.)	'Berl. Klin. Wochensch. xxxv. 283–285 ; 'Chem. Centr.' 1898, I. 1002. (Abs.)

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E. Demarçay	Sur le spectre et la nature du néodyme. (Read April 4.)	'C. R.' cxxvi. 1037–1041; 'Beiblätter,' xxiii. 401 (Abs.); 'J. Chem. Soc.' lxxiv. II. 518–519 (Abs.); 'Chem. News,' lxxvii. 219–220.
R. Zsigmondy	Ueber wässerige Lösungen metallischen Goldes. (April.)	'Ann. Chem. u. Pharm.' ccci. 29–54; 'J. Chem. Soc.' lxxiv. II. 522–523 (Abs.)
K. Ångström	Om absorptions fermogen hos en sotad yta. (Read May 11.)	'Oefvers. af K. Vet. Akad. Förh.' lv. 283–295; 'Beiblätter,' xxiii. 97–98 (Abs.)
A. Étard and Bouilhac	Présence des chlorophylles dans un Nostoc cultivé à l'abri de la lumière. (Read July 11.)	'C. R.' cxxvii. 119–121; 'Chem. Centr.' 1898, II. 493–494 (Abs.)
R. von Zeynek	Ueber das Hämochromogen. (July.)	'Zeitschr. f. physiol. Chem.' xxv. 492–506; 'Chem. Centr.' 1898, II. 122–123 (Abs.); 'J. Chem. Soc.' lxxiv. I. 720 (Abs.)
G. D. Liveing	On the Variation of Intensity of the Absorption-Bands of different Didymium Salts dissolved in water, and its bearing on the Ionisation Theory of the Colour of Solutions of Salts. (Read Nov. 28.)	'Proc. Phil. Soc. Camb.' x. 40–44; 'Science Abstr.' ii. 379–380 (Abs.); 'Nature,' lix. 142 (Abs.)
E. Deussen	Ueber die Absorption des Uranylsalze. (Dec.)	'Ann. Phys. u. Chem.' [N.F.], lxvi. 1128–1148; 'Nature,' lix. 347 (Abs.); 'Science Abstr.' ii. 78.
S. Försling	Om praseodidyms spectra.	'Bihang till K. Vet. Svensk. Akad. Handl.' xxii. I. No. 5, 20 pp.
K. Ibsen	Ein Beitrag zum Blutnachweis. (Vierteljahrschrift für gericht. Med. 1898, 111.)	'Chem. Centr.' 1898, I. 417–418 (Abs.)
G. J. Katz	Verschiebung der Absorptionsstreifen in verschiedenen Lösungsmitteln. (Inaug. Diss. Erlangen, 33 pp.)	'Beiblätter,' xxii. 774–775 (Abs.)
C. von Scheele	Ueber Praseodidym und dessen wichtigste Verbindungen.	'Zeitschr. f. anorg. Chem.' xvii. 310–326; 'J. Chem. Soc.' lxxiv. II. 519–520 (Abs.)

1899.

H. Kreusler	Eine einfache Methode für die Umkehrung des Natriumspectrum. (Jan.)	'Chem. Zeitung,' xxiii. 37; 'J. Chem. Soc.' lxxvi. II. 717 (Abs.)
P. Baccei	Sullo spettro di assorbimento dei gas. (Jan.)	'Il Nuovo Cimento' [4], ix. 177–191; 'Beiblätter,' xxiii. 635–636 (Abs.); 'Science Abstr.' ii. 603.

ABSORPTION SPECTRA, 1899.

A. Dastre and N. Floresco	Contributions à l'étude des chlorophylles animales. Chlorophylle du foie des invertébrés. (Read Feb. 13.)	'C. R.' cxxviii. 398–400; 'J. Chem. Soc.' lxxvi. II. 374 (Abs.)
W. N. Hartley and J. J. Dobbie	A Study of the Absorption Spectrum of Isatin, Carbostyril, and their Alkyl Derivatives, in relation to Tautomerism. (Read Feb. 16.)	'J. Chem. Soc.' lxxv. I. 640–661; 'Proc. Chem. Soc.' xv. 47–48 (Abs.); 'Chem. News,' lxxix. 101. (Abs.); 'Chem. Centr.' 1899, I. 788–789 (Abs.)
W. N. Hartley	On the Absorption Spectrum and Constitution attributed to Cyanuric Acid. (Read Feb. 16.)	'Proc. Chem. Soc.' xv. 46–47 (Abs.); 'Chem. News,' lxxix. 101 (Abs.); 'Chem. Centr.' 1899, I. 784 (Abs.)
A. Etard	Les chlorophylles. (April.)	'Ann. Chim. et Phys.' [7], xiii. 556–574.
C. A. Schunck	Yellow Colouring Matters accompanying Chlorophyll, and their Spectroscopic Relations. (Read May 18.)	'Proc. Roy. Soc.' lxv. 177–186; 'J. Chem. Soc.' lxxxviii. II. 36–37 (Abs.)
G. D. Liveing	On the Influence of Dilution, Temperature, and other circumstances, on the Absorption Spectra of Didymium and Erbium Salts. (Read June 5.) ('Trans. Phil. Soc. Cambridge,' xviii. 298–315.)	'J. Chem. Soc.' lxxviii. II. 517 (Abs.)
A. Wynter Blyth.	The Ultra-violet Absorption Spectra of Albuminoids in relation to that of Tyrosin. (Read June 15.)	'J. Chem. Soc.' lxxv. 1162–1166; 'Proc. Chem. Soc.' xv. 175–176 (Abs.); 'Chem. Centr.' 1899, II. 257 (Abs.); 'Chem. News,' lxxx. 32 (Abs.)
W. N. Hartley, F. R. Japp, and J. J. Dobbie.	Report on the Relation between the Absorption Spectra and Chemical Constitution of Organic Substances. (Interim Report.) (Sept.)	'Brit. Assoc. Report,' 1899, 316–358.
W. Muthmann and L. Stützel.	Beiträge zur Spectralanalyse von Neodym und Praseodym. (Read Oct. 4.)	'Ber.' xxxii. 2653–2677; 'Chem. Centr.' 1899, II. 931–933 (Abs.); 'J. Chem. Soc.' lxxviii. II. 18–19 (Abs.); 'Beiblätter,' xxiv. 478 (Abs.)
L. Puccianti	Ueber die Absorptionsspectren der Kohlenstoffverbindungen im Ultrarot. (Vorläufige Mittheilung.) (Oct.)	'Phys. Zeitschr.' i. 49–52; 'J. Chem. Soc.' lxxviii. II. 585 (Abs.)
G. D. Liveing	On the Influence of Temperature and of Various Solvents on the Absorption Spectra of Didymium and Erbium Salts. (Read Nov. 27.)	'Proc. Phil. Soc. Cambridge,' x. 213–214; 'Science Abstr.' iii. 530–531; 'Nature,' lxi. 214–215 (Abs.)

ABSORPTION SPECTRA, 1899, 1900.

S. Förslïng	Om Absorptionsspectra hos Erbium, Holmium och Thulium.	'Bihang till K. Vet. Akad. Handl.' xxiv. I. No. 7, 35 pp.; 'Beiblätter,' xxiv. 477-478 (Abs.)
G. Bode	Ueber Phylloxanthin. ('Bot. Centralbl.' xx. 227-239.)	'Chem. Centr.' 1899, II. 529 (Abs.)
P. Baccei	Sullo spettro di assorbimento delle mescolanze gassose.	'Il Nuovo Cimento' [4], ix. 241-253; 'Beiblätter,' xxiii. 636-637 (Abs.)
V. Arnold	Ein Beitrag zur Spectroscopie des Blutes. ('Centr. med. Wiss.' xxxvii. 465-468.)	'Chem. Centr.' 1899, II. 344 (Abs.); 'J. Chem. Soc.' lxxviii. I. 127 (Abs.)

1900.

V. Arnold	Ueber das neutrale Hämatin-spectrum. ('Centrabl. f. med. Wiss.' xxxvii. 833-836, 849-851.)	'Chem. Centr.' 1900, I. 209 (Abs.)
W. N. Hartley and J. J. Dobbie.	The Absorption Spectra of Ammonia, Methylamine, Hydroxylamine, Aldoxime, and Acetoxime. (Read Feb. 1.)	'J. Chem. Soc.' lxxvii. I. 318-327; 'Proc. Chem. Soc.' xvi. 14-15 (Abs.); 'Chem. News,' lxxxi. 81 (Abs.); 'Chem. Centr.' 1900, I. 581 (Abs.)
E. Marchlewski	Phyllorubin, ein neues Derivat des Chlorophylls. (Read Feb. 5.)	'Bull. Akad. Cracow,' 1900, 63-64; 'Nature,' lxiii. 66 (Abs.)
W. N. Hartley	The Action of Heat on the Absorption Spectra and Chemical Constitution of Saline Solutions (Read Feb. 21.)	'Trans. Roy. Soc. Dublin' [2], vii. 253-312; 'Nature,' lxiii. 313 (Abs.); 'J. Chem. Soc.' lxxx. II. 53 (Abs.)
W. N. Hartley and J. J. Dobbie.	Spectrographic Studies in Tautomerism. The Absorption Curves of the Ethyl Esters of Dibenzoylsuccinic Acid. (Read March 1.)	'J. Chem. Soc.' lxxvii. I. 498-509; 'Proc. Chem. Soc.' xvi. 57-58; 'Chem. Centr.' 1900, I. 750 (Abs.)
M. Radais	Sur la culture pure d'une algue verte; formation de chlorophylle à l'obscurité. (Read March 19.)	'C. R.' cxxx. 793-796; 'J. Chem. Soc.' lxxviii. II. 362 (Abs.); 'Nature,' lxi. 532 (Abs.)
B. Glatzel	Bestimmung von Absorptions-coëfficienten im ultravioletten Spectralgebiete. (May.)	'Phys. Zeitschr.' i. 285-287; 'Beiblätter,' xxiv. 476-477 (Abs.); 'Science Abstr.' iii. 688.
L. Puccianti	Spettri di assorbimento di liquidi nell' ultrarosso. (May.)	'Il Nuovo Cimento' [4], xi. 241-278; 'Beiblätter,' xxiv. 1122-1123 (Abs.); 'Science Abstr.' iii. 783.
W. N. Hartley and J. J. Dobbie.	The Ultra-violet Absorption Spectra of some Closed-chain Carbon Compounds. II. Dimethylpyrazine, Hexamethylene, and Tetrahydrobenzene. (Read June 7.)	'J. Chem. Soc.' lxxvii. I. 846-850; 'Proc. Chem. Soc.' xvi. 129-130 (Abs.); 'Chem. News,' lxxxi. 307 (Abs.)

ABSORPTION SPECTRA, 1900.

W. N. Hartley, J. J. Dobbie, and P. G. Palliatseas.	A Study of the Absorption Spectra of o-Oxycarbonil and its Alkyl-derivatives, in Relation to Tautomerism. (Read June 7.)	'J. Chem. Soc.' lxxvii. I. 839–845; 'Proc. Chem. Soc.' xvi. 130–131 (Abs.); 'Chem. News,' lxxxi. 307 (Abs.)
L. Marchlewski and C. A. Schunck.	Notes on the Chemistry of Chlorophyll. (Read June 21.)	'J. Chem. Soc.' lxxvii. 1080–1094; 'Proc. Chem. Soc.' xvi. 148–149 (Abs.)
J. Formánek .	Der Farbstoff der roten Reihe und sein Absorptionsspectrum. (Oct.)	'J. prakt. Chem.' [2] lxii. 310–314; 'J. Chem. Soc.' lxxx. 35 (Abs.)
P. Lemoult	Relation entre la constitution chimique des colorants du triphénylmethane et les spectres d'absorption de leurs solutions aqueuses. (Read Nov. 19.)	'C. R.' cxxxi. 839–842; 'Beiblätter,' xxv. 36 (Abs.); 'Chem. News,' lxxxii. 290–291; 'Nature,' lxiii. 124 (Abs.)
Sir J. N. Lockyer .	Further Note on the Spectrum of Silicium. (Read Nov. 22.)	'Proc. Roy. Soc.' lxvii. 403–409.
A. Miethe	Photographische Platten zur Aufnahme von Absorptionsspectrum. (Nov.)	'Zeitschr. f. angew. Chem.' 1900, 1199–2000; 'Chem. Centr.' 1901, I. 12–13 (Abs.)
C. Camichel . .	Remarques sur le Note de M. Lemoult intitulée: Relation entre la constitution chimique des colorants du triphénylmethane et les spectres d'absorption de leurs solutions aqueuses. (Read Dec. 10.)	'C. R.' cxxxi. 1001–1002; 'Chem. News,' lxxxiii. 11 (Abs.); 'Beiblätter,' xxv. 36 (Abs.)
J. Formánek .	Nachweis der Metallsalze mittels der Absorptionsspectralanalyse unter Verwendung von Alkanna. I., II.	'Zeitschr. anal. Chem.' xxxix. 409–434, 673–693; 'Chem. Centr.' 1900, II. 741 (Abs.); 'J. Chem. Soc.' lxxviii. II. 687 (Abs.), lxxx. II. 128–129 (Abs.)
B. Glatzel	Quantitative Untersuchungen über Absorption und Reflexion im Ultraviolett.	'Phys. Zeitschr.' ii. 173–178; 'Beiblätter,' xxv. 35 (Abs.); 'Science Abstr.' iv. 223–224.
R. Kobert	Beiträge zur Kenntniss des Methämoglobine.	'Arch. f. d. gesammte Physiol.' lxxxii. 603–630; 'Chem. Centr.' 1901, I. 51–52 (Abs.); 'J. Chem. Soc.' lxxx. I. 242–243 (Abs.)
H. J. Möller .	Ueber gefärbte Gläser. II. Die spectralanalytische Untersuchung der Gläser ('Ber. Deutsch. pharm. Gesellsch.' x. 234–264.)	'Chem. Centr.' 1900, II. 1286–1287 (Abs.)

IV.

PHYSICAL RELATIONS.

1896.

H. Th. Simon	Ueber ein neues photographisches Photometrirverfahren, und seine Anwendung auf die Photometrie des ultravioletten Spectralgebietes.	'Ann. Phys. u. Chem.' [N.F.], lix. 90–115; 'Astrophys. J.' v. 69–70 (Abs.); 'Science Abstr.' i. 55.

1897

J. Widmark	Om gränsen för det synliga spectrum. (Read May 12.)	'Oefvers. af K. Vet. Akad. Förh.' liv. 287–307; 'Beiblätter,' xxii. 573 (Abs.)
A. König	Die Abhängigkeit der Farben- und Helligkeitsglühungen von der absoluten Intensität. (Read July 29.)	'Sitzungsb. Akad. Berlin,' 1897, 871–882; 'Beiblätter,' xxii. 575–576 (Abs.)
D. Dijken	Die Molecularrefraction und Dispersion äusserst verdünnter Salzlösungen unter Berücksichtigung der Dissociation.	'Zeitschr. f. physikal. Chem.' xxiv. 81–113; 'J. Chem. Soc.' lxxiv. II. 1 (Abs.)
W. König	Einfache Demonstration des Zeeman'schen Phänomens.	'Ann. Phys. u. Chem.' [N.F.], lxiii. 268–272; 'Science Abstr.' i. 131.
H. Becquerel	Sur une interprétation applicable au phénomène de Faraday et au phénomène de Zeeman. (Read Nov. 5.)	'C. R.' cxxv. 679–685; 'J. de Phys.' [3], vi. 681–688; 'Science Abstr.' i. 56–58; 'Nature,' lvii. 72 (Abs.)
T. Preston	Radiation Phenomena in a strong Magnetic Field. I. (Read Dec. 22.)	'Trans. Roy. Soc. Dubl.' [2] vi. 385–392; 'Nature,' lvii. 239 (Abs.); 'Science Abstr.' i. 538.
	The Zeeman Effect photographed. (Dec.)	'Nature,' lvii. 173.
H. Becquerel	Explication de quelques expériences de M. G. le Bon.	'J. de Phys.' [3], vi. 525–528; 'Nature,' lvi. 619 (Abs.)
P. Carnazzi	Influenza della pressione sull' indice di rifrazione dei gas.	'Il Nuovo Cimento' [4], vi. 385–400; 'Beiblätter,' xxii. 661 (Abs.); 'Science Abstr.' i. 383–384.
T. W. Engelmann	Tafeln und Tabellen zur Darstellung der Ergebnisse spectroscopischen u. spectrophotometrischen Beobachtungen. (Book, Leipzig.)	'Beiblätter,' xxii. 62–63 (notice).

1898.

A. Perot and C. Fabry.	Sur une nouvelle méthode de spectroscopie interférentielle. (Read Jan. 3.)	'C. R.' cxxvi. 34–36; 'Nature,' lvii. 263 (Abs.); 'Beiblätter,' xxii. 567 (Abs.)

PHYSICAL RELATIONS, 1898.

A. Cornu	Sur quelques résultats nouveaux relatifs au phénomène decouvert par M. le Dr. Zeeman. (Read Jan. 17.)	'C. R.' cxxvi. 181–186; 'Nature,' lvii. 310 (Abs.); 'Science Abstr.' i. 59.
T. Preston	On the Modifications of the Spectra of Iron and other Substances radiating in a Magnetic Field. (Read Jan. 20.)	'Proc. Roy. Soc.' lxiii. 26–31; 'Beiblätter,' xxiii. 299–300 (Abs.); 'Science Abstr.' i. 386.
A. Cornu	Additions à ma note précédente sur le phénomène de Zeeman. (Read Jan. 24.)	'C. R.' cxxvi. 300–301; 'Nature, lvii. 335 (Abs.)
P. Daude	Die optische Constanten des Natriums. (Jan.)	'Ann. Phys. u. Chem.' [N.F.], lxiv. 159–162; 'J. Chem. Soc.' lxxiv. II. 273–274 (Abs.); 'Science Abstr.' i. 382.
G. J. Burch	On Artificial Temporary Colour-blindness, with an Examination of the Colour Sensations of 109 Persons. (Read Feb. 17.)	'Phil. Trans.' cxci. 1–34; 'Proc. Roy. Soc.' lxiii. 35–38 (Abs.)
H. A. Lorentz	Optische Verschijnselen die met de Lading en de Massa der Ionen in Verband stand. (Read Feb. 26.)	'Zittingsversl. d. K. Vet. Akad. Amsterdam,' vi. 506–529, 555–565; 'Beiblätter,' xxiii. 51–53 (Abs.); 'Nature,' lviii. 48 (Abs.)
P. Zeeman	Measurements concerning Radiation Phenomena in a Magnetic Field. (Feb.)	'Phil. Mag.' [5], xlv. 197–201; 'Science Abstr.' i. 250.
G. Abati	Ueber des Refractions- und Dispersionsvermögen des Siliciums in seinen Verbindungen. (Feb.)	'Zeitschr. f. physikal. Chem.' xxv. 353–364; 'Beiblätter,' xxii. 397–398 (Abs.); 'Chem. News,' lxxvii. 271 (Abs.)
J. Stscheglayew	Ueber das Brechungsvermögen des mit Flüssigkeiten getränkten Hydrophans. (Feb.)	'Ann. Phys. u. Chem.' [N.F.], lxiv. 325–332; 'Science Abstr.' i. 382.
A. Cotton	Sur les expériences d'Egoroff et Georgiewsky, et l'explication de Lorenz. (Feb.)	'L'Éclairage électrique,' xiv. 299–300; 'Science Abstr.' i. 390.
A. A. Michelson	Radiation in a Magnetic Field. (Feb.)	'Astrophys. J.' vii. 131–138; 'Phil. Mag.' [5], xlv. 348–356; 'Science Abstr.' i. 537–538.
E. Carvallo	Recherches de précision sur la dispersion infra-rouge du quartz. (Read March 7.)	'C. R.' cxxvi. 728–731; 'Beiblätter,' xxiii. 31–32 (Abs.); 'Nature,' lvii. 472 (Abs.)
R. A. Lehfeldt	On the Properties of Liquid Mixtures. Part II. (Read March 11.)	'Proc. Phys. Soc.' xvi. 83–102.
W. N. Hartley and H. Ramage.	A Determination of the Wave-lengths of the Principal Lines in the Spectrum of Gallium, showing their Identity with two Lines in the Solar Spectrum. (Read March 16.)	'Trans. Roy. Soc. Dublin' [2], vii. 1–6; 'Astrophys. J.' ix. 214–220; 'Beiblätter,' xxiv. 107, 108 (Abs.); 'Science Abstr.' ii. 816–817.

PHYSICAL RELATIONS, 1898.

A. Cotton . .	Radiations dans un champ magnétique. II. Renversement des raies de sodium, et application. (March.)	'L'Éclairage électrique,' xiv. 540–547; 'Beiblätter,' xxii. 890–891 (Abs.)
H. Becquerel and H. Deslandres	Contribution à l'étude du phénomène de Zeeman. (Read April 4.)	'C. R.' cxxvi. 997–1001; 'J. Chem. Soc.' lxxiv. II. 493–494 (Abs.); 'Science Abstr.' ii. 12.
E. S. Ferry . .	Ueber das Verhältniss der Spannung des electrischen Strömes und der Stärke der Strahlung der Spectra reiner Gase in Vakuumröhren. (Read April 13.)	'Oefvers. af K. Vet. Akad. Förh.' lv. 189–198; 'Beiblätter,' xxii. 900–901 (Abs.)
H. G. Madan . .	On some Organic Substances of High Refractivity, available for Mounting Specimens for Examination under the Microscope. (Read April 20.)	'J. Roy. Micro. Soc.' 1898, 273–281, 385–386; 'Beiblätter,' xxii. 769–770 (Abs.)
H. Dufet . .	Sur les propriétés optiques du calomel (protochlorure de mercure). (Read April 21.)	'Bull. Soc. Franç. Min.' xxi. 90–94; 'Beiblätter,' xxiii. 32–33 (Abs.)
T. Preston . .	Radiation Phenomena in the Magnetic Field. (April.)	'Phil. Mag.' [5], xlv. 325–339; 'Beiblätter,' xxii. 888–889 (Abs.)
T. C. Porter . .	Contributions to the Study of Flicker. (Read May 26.)	'Proc. Roy. Soc.' lxiii. 347–356; 'Science Abstr.' i. 691–692; 'Beiblätter,' xxii. 855–856 (Abs.); 'Nature,' lviii. 188 (Abs.)
D. Edser and C. Butler.	A Simple Method of Reducing Prismatic Spectra. (Read May 27.)	'Proc. Phys. Soc.' xvi. 207–218; 'Phil Mag.' [5] xlvi. 207–216; 'Nature,' lviii. 119 (Abs.); 'Chem News,' lxxvii. 260 (Abs.)
C. Klein . .	Die Anwendung der Methode der Total-reflexion in der Petrographie. (Read May 26.)	'Sitzungsb. Akad. Berlin,' 1898, 317–331.
P. Zeeman	Over eene Asymmetrie in de Verandering der Spectraallijnen van Ijzen bij Straling in een magnetisch Veld. (Read June 25.)	'Zittingsversl. d. K. Vet. Akad. Amsterdam,' vii. 122–124; 'Beiblätter,' xxii. 890 (Abs.)
H. A. Lorentz	Beschoningen over dem Invloed van een magnetisch Veld op de Uitstraling van Licht. (Read June 25.)	'Zittingsversl. d. K. Vet. Akad. Amsterdam,' vii. 113–122; 'Beiblätter,' xxiii. 49–51 (Abs.)
C. E. Mendenhall and F. A. Saunders.	The Energy Spectrum of an absolutely Black Body. (June.)	'Johns Hopkins Univ. Circ' xvii. 55; 'Naturw. Rundschau,' xiii. 457; 'Beiblätter,' xxii. 770–771 (Abs.)
A. Trowbridge .	Ueber die Dispersion des Sylvins, und das Reflexionsvormögen der Metalle. (June.)	'Ann. Phys. u. Chem.' [N.F.], lxv. 595–620; 'Science Abstr.' i. 690.

PHYSICAL RELATIONS, 1898.

C. L. Poor & S. A. Mitchell.	The Concave Grating for Stellar Photography. (June.)	'Johns Hopkins Univ. Circ.' cxxxv. 61–62; 'Astrophys. J.' vii. 157–162; 'Nature,' lvii. 520 (Abs.)
L. E. Jewell . .	The Structure of the Shading of the H- and K- and some other Lines in the Spectrum of the Sun and Arc. (June.)	'Johns Hopkins Univ. Circ.' xvii. 62.
J. S. Ames, R. F. Carhart, and H. M. Reese.	Some Notes on the Zeeman Effect. (June.)	'Astrophys. J.' viii. 48–50; 'Johns Hopkins Univ. Circ.' xvii. 53; 'Beiblätter,' xxii. 892 (Abs.)
O. M. Corbino .	À propos de l'interprétation du phénomène de Zeeman donnée par M. Cornu. (June.)	'L'Éclairage électrique,' xv. 548–550; 'Beiblätter,' xxii. 891 (Abs.)
H. Becquerel and H. Deslandres.	Observations nouvelles sur le phénomène de Zeeman. (Read July 4.)	'C. R.' cxxvii. 18–24; 'Beiblätter,' xxii. 891–892 (Abs.); 'Nature,' lviii. 264 (Abs.); 'Science Abstr.' ii. 12–13.
E. Aschkinass .	Ueber die Emission des Quarzes in dem Spectralbereiche seiner metallischen Absorption. (Read July 8.)	'Verh. phys. Ges. Berlin,' xvii. 101–105; 'Beiblätter,' xxiii. 357–358 (Abs.)
A. König . .	Ueber 'Blaublindheit.' (Read July 8.)	'Sitzungsb. Akad. Berlin,' 1898, 718–731; 'Beiblätter,' xxii. 575 (Abs.)
A. Righi . .	Di un nuovo metodo sperimentale per lo studio dell' assorbimento della luce nel campo magnetico. I. (Read July 17.)	'Rend. R. Accad. d. Lincei' [5], vii. II. 41–46; 'Il Nuovo Cimento,' [4], viii. 102–109; 'Beiblätter,' xxiii. 300–302 (Abs.); 'Science Abstr.' ii. 661.
" . .	Sur l'absorption de la lumière produite par un corps placé dans un champ magnétique. (Read July 25.)	'C. R.' cxxvii. 216–219; 'Sitzungsb. Akad. Berlin,' xxviii. 600–604; 'Beiblätter,' xxiii. 300–302 (Abs.); 'Nature,' lix. 263 (Abs.)
E. S. Ferry . .	On the Relation between Pressure, Current, and Luminosity of the Spectra of Pure Gases in Vacuum Tubes. (July.)	'Phys. Review,' vii. 1–9; 'Science Abstr.' ii. 15; 'Nature,' lviii. 463 (Abs.)
J. A. Reed . .	Ueber den Einfluss der Temperatur auf die Brechung und Dispersion einiger Krystalle und Gläser. (July.)	'Ann. Phys. u. Chem.' [N.F.], lxv. 707–744; 'Science Abstr.' i. 690.
J. Stscheglayew .	Nachtrag zu der Abhandlung 'Ueber das Brechungsvermögen des mit Flüssigkeiten getränkten Hydrophans.' (July.)	'Ann. Phys. u. Chem.' [N.F.], lxv. 745.
F. F. Martens	Streifen gleicher Helligkeit beim Durchgang des Lichtes durch zwei grob getheilte Gitter. (Aug.)	'Zeitschr. f. Instrumentenkunde' ('Beiblätter'), 1898, 121; 'Science Abstr.' ii. 163–164.

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T. E. Doubt .	Colour Measurement. (Aug.)	'Phil. Mag.' [5], xlvi. 216–222; 'Science Abstr.' ii. 93–94.
D. Macaluso and O. M. Corbino.	Sopra una nuova azione che la luce subisce attraversando alcuni vapori metallici in un campo magnetico. (Read Sept. 22.)	'Rend. R. Accad. d. Lincei,' [5], vii. II. 292–301; viii. I. 38–41; 'Il Nuovo Cimento' [4], viii. 257–259; 'Beiblätter,' xxiii. 672–673 (Abs.)
S. P. Thompson .	On the Discovery by Righi of the Absorption of Light in a Magnetic Field. (Sept.)	'Brit. Assoc. Rep.' 1898, 789–790.
D. Macaluso and O. M. Corbino .	Sur une nouvelle action subie par la lumière traversant certaines vapeurs métalliques dans un champ magnétique. (Read Oct. 30.)	'C. R.' cxxvii. 548–551; 'Beiblätter,' xxiii. 298–299 (Abs.); 'Science Abstr.' ii. 167–169; 'Nature,' lviii. 635 (Abs.)
W. Voigt . .	Ueber d. Zusammenhang zwischen dem Zeeman'schen und dem Faraday'schen Phänomen. (Read Oct. 29.)	'Gött. Nachr.' 1898, iv. 329–344: 'Science Abstr.' ii. 601–602.
H. Becquerel . .	Remarques sur la polarisation rotatoire magnétique et la dispersion anomale à l'occasion d'une expérience nouvelle de MM. Macaluso et O. M. Corbino. (Read Oct. 31.)	'C. R.' cxxvii. 647–651. 'Nature,' lix. 47 (Abs.)
R. W. Wood . .	On the anomalous Dispersion of Cyanin. (Oct.)	'Phil. Mag.' [5], xlvi. 380–386; 'Science Abstr.' ii. 279 (Abs.); 'Beiblätter,' xxiii. 983 (Abs.)
C. Pulfrich . .	Ueber die Anwendbarkeit der Methode der Totalreflexion auf kleine und mangelhafte Krystalflächen. (Oct.)	'Zeitschr. f. Krystallogr.' xxx. 568–586; 'Beiblätter,' xxiii. 354–355 (Abs.)
J. Hartmann . .	Ueber die Scale des Kirchhoff'schen Sonnenspectrum. (Read Nov. 17.)	'Sitzungsb. Akad. Berlin,' 1898, 742–756; 'Science Abstr.' ii. 347.
W. Voigt . .	Doppelbrechung von im Magnetfelde befindlichem Natriumdampf in der Richtung normal zu den Kraftlinien. (Read Nov. 26.)	'Gött. Nachr.' 1898, iv. 356–360; 'Science Abstr.' ii. 602.
A. Cotton . .	Absorption dans un champ magnétique. (Read Dec. 5.)	'C. R.' cxxvii. 953–955; 'Science Abstr.' ii. 164–165.
H. Becquerel.	Sur la dispersion anomale et le pouvoir rotatoire magnétique de certaines vapeurs incandescentes. (Read Dec. 5.)	'C. R.' cxxvii. 899–904; 'Beiblätter,' xxiii. 509 (Abs.); 'Nature,' lix. 167 (Abs.); 'Science Abstr.' ii. 169.

PHYSICAL RELATIONS, 1898.

J. Dewar	Application of Liquid Hydrogen to the Production of High Vacua, together with their Spectroscopic Examination. (Read Dec. 15.)	'Proc. Roy. Soc.' lxiv. 231–238; 'Science Abstr.' ii. 247 (Abs.); 'Nature,' lix. 280–281; 'Chem. News,' lxxix. 73–75; 'Chem. Centr.' 1899, I. 819–820 (Abs.); 'J. Chem. Soc.' lxxvi. II. 741–742 (Abs.)
W. Ramsay and M. W. Travers .	The Preparation and some of the Properties of Pure Argon. (Read Dec. 15.)	'Proc. Roy. Soc.' lxiv. 183–192; 'Nature,' lix. 308–309 (Abs.); 'Chem. News,' lxxix. 37–39, 49–50; 'Chem. Centralbl.' 1899, I. 469–470 (Abs.)
E. Hagen and H. Rubens . .	Ueber das Reflexionsvermögen von Metallen. (Read Dec. 16.)	'Verh. Deutsch. phys. Gesellsch.' xvii. 143–147; 'Science Abstr.' ii. 439–440.
A. Righi . .	Di un nuovo metodo sperimentale per lo studio dell' assorbimento della luce nel campo magnetico. II. (Read Dec. 18.)	'Rend. R. Accad. d. Lincei' [5], vii. II. 333–338; 'Il Nuovo Cimento' [4], ix. 295–302; 'Beiblätter,' xxiii. 670–671 (Abs.)
E. S. Ferry . .	A Photometric Study of the Spectra of Mixtures of Gases at Low Pressures. (Dec.)	'Phys. Review,' vii. 296–306.
E. van Aubel . .	Action de magnétisme sur les spectres des gaz.	'J. de Phys.' [3] vii. 408–409; 'Chem. Centr.' 1898, II. 1160 (Abs.); 'Science Abstr.' ii. 170.
R. Dongier . .	Méthode de contrôle de l'orientation des faces polies d'un quartz épais normal à l'axe.	'J. de Phys.' [3], vii. 643–648; 'Science Abstr.' ii. 277.
I. Kanonnikoff .	Ueber Lichtbrechungsvermögen der Körper in flüssigem und gasförmigem Zustande.	'J. Russ. phys.-chem. Ges.' xxx. 965–975; 'Chem. Centr.' 1899, I. 581 (Abs.)
E. S. King	Conversion of Prismatic into Normal Spectra. (Harvard Astronomical Conference.)	'Nature,' lix. 330 (Abs.)
E. Matthiessen	Ueber den Einfluss des Prozentgehaltes und der Temperatur auf das Brechungsvermögen von einigen Zuckerlösungen. (Inaug. Diss. Rostock, 1898, 34 pp.)	'Beiblätter,' xxii. 557–558 (Abs.)
A. E. Schiotz	Ueber das Spectrum der Kathodenstrahlen ('Christiania Vidensk. Selsk. Forh.' 1898, 6 pp.)	'Beiblätter,' xxiii. [9]. (title).
E. S. Shepherd	Photographic plates and the spectrum. ('Journ. Camera Club,' xii. No. 150.)	'Nature,' lix. 83–84 (Abs.)
E. E. Sundwik .	Ueber die Refraction von Lösungen und eine einfache Methode den Gehalt der Lösungen vermittelst der Refraction zu Bestimmen. (Chem. Centr. Halle, xxxix. 681–685.)	'Chem. Centr.' 1898, II. 847 (Abs.)

PHYSICAL RELATIONS, 1898, 1899.

R. Thalen	Ueber der absolute Bestimmung der Wellenlängen einiger Strahlen des Sonnenspectrums. ('Roy. Soc. Upsala' [3] (1898.)	'Beiblätter,' xxiv. 472–473 (Abs.)
P. Zeeman	Sur les doublets et les triplets produits dans le spectre par des forces magnétiques extérieures.	'Arch. néerland.' [2], i. 383–392.

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A. Righi	Sur l'absorption de la lumière par un corps placé dans un champ magnétique. (Read Jan. 2.)	'C. R.' cxxviii. 47–48; 'Beiblätter,' xxiii. 510 (Abs.); 'Science Abstr.' ii. 167.
D. Macaluso and O. M. Corbino	Sulle modificazioni che la luce subisce attraversando alcuni vapori metallici in un campo magnetico. (Read Jan. 8.)	'Rend. R.Accad. d. Lincei' [5] viii.I.38–41; 'Science Abstr.' ii. 346.
H. Becquerel	Sur la dispersion anomale de la vapeur de sodium incandescente, et sur quelques conséquences de ce phénomène. (Read Jan. 16.)	'C. R.' cxxviii. 145–151; 'Beiblätter,' xxiii. 352–353 (Abs.); 'J. Chem. Soc.' lxxvi. II. 266 (Abs.); 'Science Abstr.' ii. 442–443; 'Nature,' lix. 311 (Abs.)
T. Preston	Radiating Phenomena in a Strong Magnetic Field. Part II. Magnetic Perturbations of the Spectral Lines. (Read Jan. 18.)	'Trans. Roy. Soc. Dublin' [2], vii. 7–22; 'Nature,' lvii. 431 (Abs.)
Sir J. Conroy	On the Refractive Indices and Densities of Normal Solutions and Semi-normal Aqueous Solutions of Hydrogen Chloride and the Chlorides of the Alkalis. (Read Jan. 19.)	'Proc. Roy. Soc.' lxiv. 308–318; 'Science Abstr.' ii. 505–506; 'J. Chem. Soc.' lxxvi. II. 717 (Abs.)
H. A. Lorentz	Trillingen van electrisch geladen Stelsels in een magnetisch Veld. (Read Jan. 26.)	'Zittingsversl. d. K. Vet. Akad. Amsterdam,' vii. 320–340.
A. Cotton	Biréfringence produite par le champ magnétique, liée au phénomène de Zeeman. (Read Jan. 30.)	'C. R.' cxxviii. 294–297; 'Beiblätter,' xxiii. 509–510 (Abs.); 'Nature,' lix. 359 (Abs.); 'Science Abstr.' ii. 220–221.
G. Johnstone Stoney.	Illusory Resolution of the Lines of a Spectrum. (Jan.)	'Nature,' lix. 294–295.
T. Preston	Radiation Phenomena in the Magnetic Field. (Jan.)	'Nature,' lix. 224–229.
C. E. Guillaume	L'échelle du spectre. (Jan.)	'Rev. générale des Sciences,' x. 5–8; 'Beiblätter,' xxiv. 259 (Abs.)
C. Fabry and A. Perot.	Théorie et applications d'une nouvelle méthode de spectroscopie interférentielle. (Jan.)	'Ann. Chim. et Phys.' [7], xvi. 115–144.
A. Schuster and G. Hemsalech.	On the Constitution of the Electric Spark. (Read Feb. 2.)	'Phil. Trans.' cxciii. A. 189–213; 'Beiblätter,' xxiv. 552–554 (Abs.)

O. Lummer and E. Pringsheim.	Die Vertheilung der Energie im Spectrum der schwarzen Körper. (Read Feb. 3.)	'Verh. Deutsch. phys-Gesellsch.' i. 23-41. 'Science Abstr.' ii. 664.
D. Macaluso and O. M. Corbino.	Sulla relazione tra il fenomeno di Zeeman e la rotazione magnetica anomala del piano di polarizzazione della luce. (Read Feb. 5.)	'Rend. R. Accad. d. Lincei' [5], viii. I. 116-121; 'Il Nuovo Cimento' [4], ix. 384-389; 'Beiblätter,' xxiii. 673-674 (Abs.)
O. M. Corbino .	Sui battimenti luminosi e sull' impossibilità di produrli ricorrendo al fenomeno di Zeeman. (Read Feb. 19.)	'Rend. R. Accad. d. Lincei' [5], viii. I. 171-175; 'Science Abstr.' ii. 346.
T. Preston . .	Magnetic Perturbations of the Spectral Lines. Further Resolution of the Quartet. (Feb.)	'Nature,' lix. 367.
" .	Radiation Phenomena in the Magnetic Field. Magnetic Perturbations of the Spectral Lines. (Feb.)	'Phil. Mag.' [5] xlvii. 165-178; 'Science Abstr.' ii. 443-444.
O. M Corbino .	Sulla dipendenza tra il fenomeno di Zeeman e le altre modificazioni che la luce subisce dai vapori metallici in un campo magnetico. (Read March 5.)	'Rend R. Accad. d. Lincei' [6], viii. I. 250-255.
Lord Rayleigh .	Transparency and Opacity. (Read March 24.)	'Proc. Roy. Inst.' xvi. 116-119; 'Nature,' lx. 64-65 (Abs.)
D. A. Goldhammer	Das Zeeman'sche Phänomen, die magnetische Circularpolarisation, und die magnetische Doppelbrechung. (March.)	'Ann. Phys. u. Chem.' [N.F.], lxvii. 696-701; 'Science Abstr.' ii. 278-279.
T. Preston .	Radiation in a Magnetic Field. (March.)	'Nature,' lix. 485; 'Beiblätter,' xxiv. 835 (Abs.)
A. A. Michelson .	Radiation in a Magnetic Field. (March.)	'Nature,' lix. 440-441; 'Beiblätter,' xxiv. 835 (Abs.)
A. Righi	Intorno alla questione della produzione di un campo magnetico, per opera di un raggio luminoso polarizzato circolamente. (Read April 9.)	'Atti R. Accad. d. Lincei' [5], viii. I. 325-326; 'Science Abstr.' ii. 601.
F. Paschen	Ueber die Vertheilung der Energie im Spectrum des schwarzen Körpers bei niederen Temperaturen. (Read April 27.)	'Sitzungsb. Akad. Berlin,' 1899, 405-420; 'Beiblätter,' xxiv. 31-32 (Abs.); 'Science Abstr.' ii. 604.
Lord Rayleigh	The Interferometer. (April.)	'Nature,' lix. 533; 'Beiblätter,' xxiv. 835 (Abs.)
H. C. Lord	On a Graphic Method of Comparing the Relative Efficiencies of Different Spectroscopes (April.)	'Astrophys. J.' ix. 191-202; 'Science Abstr.' ii. 824; 'Beiblätter,' xxiii. 776-777 (Abs.)
Sir J. N. Lockyer	A Chapter in the History of Spectrum Analysis. (April.)	'Nature,' lix. 535-539.

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Lord Rayleigh	Transmission of Light through an Atmosphere containing Small Particles in Suspension. (April.)	'Phil. Mag.' [5] xlvii. 375–384; 'Science Abstr.' ii. 731.
R. W. Wood	An Application of the Diffraction Grating to Colour Photography. (April.)	'Phil. Mag.' [5] xlvii. 368–372.
L. E. Jewell	The Wave-length of $H\delta$, and the Appearance of the Solar Spectrum near the Hydrogen Lines. (April.)	'Astrophys. J.' ix. 211–213; 'Science Abstr.' ii. 823; 'Beiblätter,' xxiii. 780 (Abs.)
A. Cotton	The Present Status of Kirchhoff's Law. (April.)	'Astrophys. J.' ix. 237–268.
J. W. Brühl	Physikalische Eigenschaften einiger Campherarten und verwandter Körper.	'Ber.' xxxii. 1222–1236; 'Chem. Centr.' 1899, I. 1265–1267 (Abs.)
Sir J. N. Lockyer	On Spectrum Series. (Lecture to Working Men. May 1.)	'Nature,' lx. 368–370, 392–396.
T. Preston	Magnetic Perturbations of the Spectral Lines. (Read May 12.)	'Proc. Roy. Inst.' xvi. 151–163; 'Nature,' lx. 175–180; 'Science Abstr.' ii. 662–663.
A. Righi	Sull' assorbimento della luce per parte di un gaz posto nel campo magnetico. (Read May 28.)	'Il Nuovo Cimento' [4], x. 20–42; 'Beiblätter,' xxiii. 666–670 (Abs.); 'Nature,' lx. 276 (Abs.)
H. Wanner	Notiz über die Verbreiterung der D Linien. (May.)	'Ann. Phys. u. Chem.' [N.F.], lxviii. 143–144; 'Science Abstr.' ii. 603–604.
M. Hamy	Sur la détermination de points de repère dans le spectre. (Read June 5.)	'C. R.' cxxviii. 1380–1382; 'Science Abstr.' ii. 727 (Abs.); 'Beiblätter,' xxiii. 777–778 (Abs.)
A. Haller and P. T. Müller.	Sur les réfractions moléculaires, la dispersion moléculaire, et le pouvoir spécifique des combinaisons du camphre avec quelques aldéhydes aromatiques. (Read June 5.)	'C. R.' cxxviii. 1370–1373; 'Chem. Centr.' 1899, II. 116–117 (Abs.); 'Chem. News,' [illegible] (Abs.); 'Nature,' lx. 167 (Abs.); 'J. Chem. Soc.' lxxvi. II. 622 (Abs.)
W. de W. Abney	The Colour Sensations in Terms of Luminosity. (Read June 15.)	'Phil. Trans.' cxciii. 259–287; 'Proc. Roy. Soc.' 282–283 (Abs.); 'Nature,' lx. 237–238; 'Science Abstr.' iii. 303.
C. Bender	Brechungsexponenten reinen Wassers und normalen Salzlösungen. (June.)	'Ann. Phys. u. Chem. [N.F.] lxviii. 343–349; 'J. Chem. Soc.' lxxvi. II. 621 (Abs.); 'Science Abstr.' ii. 659.
W. W. Campbell	The Influence of the Purkinje Phenomenon on Observations of Faint Spectra. (June.)	'Astrophys. J.' x. 22–24; 'Beiblätter,' xxiii. 776 (Abs.)

PHYSICAL RELATIONS, 1899.

H. M. Reese	Notes on the Zeeman Effect. (June.)	'Johns Hopkins Univ. Circ.' xviii. 59; 'Phil. Mag.' [5] xlviii. 317–319; 'Beiblätter,' xxiv. 130–131 (Abs.)
F. A. Saunders	Notes on the Energy Spectrum of a Black Body, and on the Absorption of Ice in the Ultra-red. (June.)	'Johns Hopkins Univ. Circ.' xviii. 58–59.
J. M. Eder and E. Valenta.	Normalspectren einiger Elemente zur Wellenlängebestimmung im äussersten Ultraviolett. (Read July 13.)	'Denkschr. Akad. Wien' lxviii. 531–554; 'Beiblätter,' xxiv. 474–475 (Abs.)
J. Wilsing . .	Ueber den Einfluss des Drucks auf die Wellenlängen der Linien des Wasserstoffsspectrums. (Read July 27.)	'Sitzungsb. Akad. Berlin,' 1899, 750–752; 'Astrophys. J.' x. 269–271; 'Beiblätter,' xxiv. 475 (Abs.)
J. C. Shedd . .	An Interferometer Study of Radiation in a Magnetic Field. I., II. (July.)	'Phys. Review,' ix. 1–19, 86–115.
W. Sedgwick. .	Spectrum Series. (Aug.)	'Nature,' lx. 412.
W. W. Randall .	On the Permeation of Hot Platinum by Gases. (Aug.)	'Amer. Chem. J.' xix. 682–691; 'Chem. News,' lxxvi. 168–170.
W. König . .	Dispersionsmessungen am Gyps. (Sept.)	'Ann. Phys. u. Chem.' [N.F.], lxix. 1–11; 'Science Abstr.' ii. 819–820 (Abs.)
J. W. Gifford. .	Temperature and the Dispersion in Quartz and Calcite. (Sept.)	'Brit. Assoc. Report,' 1899, 661–662; 'Beiblätter,' xxiv. 791 (Abs.)
G. J. Burch . .	On the Spectroscopical Examination of Contrast Phenomena. (Sept.)	'Brit. Assoc. Report,' 1899, 624; 'Electrician,' xliii. 811–812; 'Nature,' lx. 585; 'Beiblätter,' xxiv. 272 (Abs.)
T. Preston . .	Preliminary Report of the Committee on Radiation from a Source of Light in a Magnetic Field. (Sept.)	'Brit. Assoc. Report,' 1899, 63–64; 'Nature,' lx. 586 (Abs.)
Fürst B. Galitzin and J. Wilip.	Untersuchungen über das Brechungsverhältniss des Aethyläthers in der Nähe des kritischen Punktes. (Read Oct. 6.)	'Bull. Akad. St. Petersb.' [5], xi. 117–196; 'Beiblätter,' xxiv. 448–450 (Abs.); 'J. Chem. Soc.' lxxviii. II. 461–462 (Abs.)
O. N. Rood	Colour Vision and the Flicker Photometer. (Oct.)	'Amer. J. Sci.' [4], viii. 254–260; 'Nature,' lx. 611 (Abs.)
E. B. Frost .	On Titanium for a Comparison Spectrum. (Oct.)	'Astrophys. J.' x. 207–208; 'Science Abstr.' iii. 20–21.

PHYSICAL RELATIONS, 1899.

O. Lummer and E. Pringsheim.	I. Die Vertheilung der Energie im Spectrum des schwarzen Körpers und des blanken Platins. II. Temperaturbestimmung fester glühender Körper. (Read Nov. 3.)	'Verh. Deutsch. phys Gesellsch.' [2], 215–235.
F. Gand . .	Sur la spectrophotometrie des lumières électriques. (Read Nov. 13.)	'C. R.' cxxix. 759–760; 'Nature,' lxi. 95 – 96 (Abs.); 'Science Abstr.' iii. 15.
A. Chilesotti	Sul potere rifrangente di alcuni idrocarburi a nuclei benzolici condensati. (Read Nov. 19.)	'Gazz. chim. Ital.' xxx. I. 149–169; 'Il Nuovo Cimento' [4], xii. 290–293 (Abs.); 'Beiblätter,' xxv. 283 (Abs.)
Sir J. N. Lockyer	Preliminary Table of Wave-lengths of Enhanced Lines. (Read Nov. 23.)	'Proc. Roy. Soc.' lxv. 452–461; 'Beiblätter,' xxiv. 262–263 (Abs.); 'Nature,' lxi. 263 (Abs.)
C. Bender . .	Brechungsexponenten reinen Wassers und normaler Salzlösungen. II. Abth. (Nov.)	'Ann. Phys. u. Chem.' [N.F.], lxix. 676–679; 'Science Absr.' iii. 13 (Abs.)
E. B. Frost . .	Corrections to Determinations of absolute Wave-length. (Nov.)	'Astrophys. J.' x. 283–285; 'Science Abstr.' iii. 176.
T. Preston . .	Some Remarks on Radiation Phenomena in a Magnetic Field. (Nov.)	'Nature,' lxi. 11–13.
F. Paschen	Ueber die Vertheilung der Energie im Spectrum des schwarzen Körpers bei höheren Temperaturen. (Read Dec. 7.)	'Sitzungsb. Akad. Berlin,' 1899, 959–976.
A. Haller and P. T. Müller.	Sur les réfractions moléculaires, la dispersion moléculaire, et le pouvoir rotatoire spécifique de quelques alcoylcamphres. (Read Dec. 11.)	'C. R.' cxxix. 1005–1008; 'Chem. Centr.' 1900, I. 297 (Abs.); 'Nature,' lxi. 192 (Abs.)
A. Righi . .	Sul fenomeno di Zeeman nel caso generale d'un raggio luminoso comunque inclinato sulla direzione della forza magnetica. (Read Dec. 17.) (Mem. Accad. Bologna [5], viii. 263–294.)	'Il Nuovo Cimento,' xi. 177–206; 'Beiblätter,' xxiv. 541–544 (Abs.); 'Science Abstr.' iii. 689.
W. H. Perkin	The Refractive and Magnetic Rotary Power of some Benzenoid Hydrocarbons. The Refractive Power of Mixtures. An Improved Spectrometer Scale-reader. (Read Dec. 21.)	'J. Chem. Soc.' lxxvii. 267–294; 'Beiblätter,' xxiv. 929–930 (Abs.); 'Chem Centr.' 1900, I. 797–798 (Abs.)
P. Zeeman	Waarnemingen over eene asymmetrische verandering van ijzerlijnen bij straling in een magnetisch veld. (Read Dec. 30.)	'Zittingsversl. R. Akad. Amsterdam,' 1899–1900, Deel viii. 328–331; 'Beiblätter,' xxiv. 835 (Abs.); 'Nature,' lxi. 408 (Abs.)
A. Wüllner	Ueber die Spectra der Canalstrahlen und Cathodenstrahlen. (Dec.)	'Phys. Zeitschr.' i. 132–134; 'Beiblätter,' xxiv. 314–315 (Abs.)

PHYSICAL RELATIONS, 1899, 1900.

Sir W. de W. Abney	Ueber die Zerlegung des Spectrums des electrischen Lichtes in Leuchtkraftmengen von drei Farben. (Jahrb. f. Photogr. 1899, 338–350.)	
E. van Aubel .	Ueber die Brechungsexponenten der Metalle.	'Zeitschr. f. physikal. Chem.' xxx. 565–567; 'Chem. Centr.' 1900, I. 161 (Abs.); 'J. Chem. Soc.' lxxviii. II. 125 (Abs.)
W. Hallwachs .	Refractive Indices of Solutions. (Sitzungsb. Isis.)	'Nature,' lx. 328–329 (Abs.)
G. A. Hemsalech .	Sur le spectre des décharges oscillantes.	'J. de Phys.' [3], viii. 652–660; 'Nature,' lxi. 258–259 (Abs.)

1900.

J. J. Manley . .	An Optical Method of determining the Density of Sea-water. (Read Jan. 8.)	'Proc. Roy. Soc. Edinb.' xxiii. 35–43; 'Nature,' lxi. 286 (Abs.)
H. Rubens . .	Recherches sur le spectre infra-rouge. La résonance électrique des rayons de chaleur. (Jan.)	'Rev. générale des Sciences,' xi. 7–13.
D. P. Brace . .	On a New System for Spectral Photometric Work. (Jan.)	'Astrophys. J.' xi. 6–24; 'Nature,' lxi. 521 (Abs.)
E. Aschkinass .	Ueber anomale Dispersion im ultrarothen Spectralgebiete. (Jan.)	'Ann. der Phys.' [4], i. 42–68; 'Phys. Zeitschr.' i. 53–54; 'Science Abstr.' iii. 237–238.
S. Young and E. C. Fortey.	Note on the Refraction and Magnetic Rotation of Hexamethylene, Chlorohexamethylene and Dichlorohexamethylene. (Read Feb. 13.)	'J. Chem. Soc.' lxxvii. 372–374; 'Beiblätter,' xxiv. 928–929 (Abs.)
C. Fabry and A. Perot.	Nouvelle source de la lumière pour le spectrométrie de précision. (Read Feb. 12.)	'C. R.' cxxx. 406–409; 'Nature,' lxi. 407 (Abs.)
A. Perot and C. Fabry.	Détermination de nouveaux points de repère dans le spectre. (Read Feb. 19.)	'C. R.' cxxx. 492–495; 'Beiblätter,' xxiv. 473–474 (Abs.); 'Nature,' lxi. 435 (Abs.)
M. Hamy . .	Sur la détermination de points de repère dans le spectre. (Read Feb. 19, March 12.)	'C. R.' cxxx. 489–492, 700–701; 'Nature,' lxi. 435 (Abs.); 'Science Abstr.' iii. 377, 464; 'Beiblätter,' xxiv. 472 (Abs.)
W. Voigt . .	Ueber eine Dissymmetrie der Zeeman'schen normalen Triplets. (Feb.)	'Ann. der Phys.' [4], i. 376–388.
E. Hagen and H. Rubens.	Das Reflexionsvermögen von Metallen und belegten Glasspiegeln. (Feb.)	'Ann. der Phys.' [4], i. 353–375; 'Nature,' lxi. 555 (Abs.)
C. Viola . .	Ueber die Minima der Lichtablenkung durch Prismen anisotroper Medien. (March.)	'Zeitschr. f. Kryst. u. Min.' xxxii. 545–550; 'Beiblätter,' xxiv. 1292–1293 (Abs.)

PHYSICAL RELATIONS, 1900.

E. H. J Cunæus	Die Bestimmung des Brechungsvermögen als Methode für die Untersuchung der Zusammensetzung der coexistirenden Phasen bei Mischungen von Aceton und Aether. (April.)	'Phys. Zeitschr.' i. 316–317; 'Science Abstr.' iii. 730.
Lord Blythswood and E. W. Marchant.	The Echelon Spectroscope and its Application to investigate the Behaviour of the Chief Lines of the Mercury Spectrum under the Influence of a Magnetic Field. (April.)	'Phil. Mag.' [5], xlix. 384–403; 'Science Abstr.' iii. 375–376.
L. E. Jewell .	The Use of the Lines of Titanium for Comparison Spectra and their Prominence in the Chromosphere. (April.)	Astrophys. J.' xi. 243–244; 'Science Abstr.' iii. 691.
D. W. Murphy .	A Method of Determining the Luminosity Curve of the Solar Spectrum. (April.)	'Astrophys. J.' xi. 220–225; 'Beiblätter,' xxiv. 910–911 (Abs.); 'Science Abstr.' iii. 691.
T. Preston . .	The Interferometer. (April) .	'Nature,' lix. 605; 'Beiblätter,' xxiv. 835–836 (Abs.)
A. Righi . .	Ueber das Zeeman'sche Phänomen in dem allgemeinen Falle eines beliebig gegen die Richtung der magnetischen Kraft geneigten Lichtstrahles. (April.)	'Phys. Zeitschr.' i. 329–334.
E. Goldstein . .	Ueber Spectra von Gasgemengen und von Entladungshüllen. (Read May 11.)	'Verb. Deutsch. phys. Gesellsch.' [2], ii. 110–112; 'Beiblätter,' xxiv. 1191–1193 (Abs.)
W. S. Adams.	The Curvature of the Spectral Lines in the Spectroheliograph. (May.)	'Astrophys. J.' xi. 309–311; 'Beiblätter,' xxiv. 908 (Abs.)
C. Bender . .	Brechungsexponenten normaler Salzlösungen. III. (May.)	'Ann. der. Phys.' [4], ii. 186–196; 'J. Chem. Soc.' lxxviii. II. 461 (Abs.)
A. Laur. . .	Ueber den normalen refractometrischen Werth von Butter. (May.)	'Chem. Zeitung,' xxiv. 394–395; 'J. Chem. Soc.' lxxviii. II. 634 (Abs.)
G. J. Burch . .	On the Spectroscopic Examination of Colour produced by Simultaneous Contrast. (Read June 21.)	'Proc. Roy. Soc.' lxvii. 224–228; 'Nature,' lxii. 615–616 (Abs.); 'Science Abstr.' iii. 181.
A. Partheil and J. von Velsen.	Die Grundlagen der refractometrischen Butteruntersuchung. (June.)	'Arch. Pharm.' ccxxxviii. 261–279; 'Chem. Centr.' 1900, II. 215–216 (Abs.)
A. Schmaus	Ueber anomale electromagnetische Rotationsdispersion. (June.)	'Ann. d. Phys.' [4], ii. 280–294; 'Nature,' lxii. 335 (Abs.)
V. Schumann	The Transparency of Thin Films of Glycerin. (June.)	'Chem. News,' lxxxi. 267–268.
G. Pellini and A. Menin.	Sul potere rifrangente del tellurio in alcuni suoi compositi. (Read July 30.)	'Gazz. chim. Ital.' xxx. II. 465–475; 'J. Chem. Soc.' lxxx. II. 94 (Abs.)

VI.

ASTRONOMICAL APPLICATIONS.

	1882.	
S. J. Perry . .	The Solar Eclipse, 1882, May 16. (June.)	'Monthly Not. R. A. S. xlii. 408–410.
	1885.	
" . .	The chromosphere in 1884 (Feb.)	'Observatory,' viii. 53.
	1889.	
S. J. Perry and A. L. Cortie .	Comparison of the Spectrum, between C and D, of a Sun-spot observed 1884, May 27, with another of 1889, May 7. (June.)	'Monthly Not. R. A. S. xlix. 410–418.
	1890.	
A. L. Cortie . .	Observation of the Spectra of Sun-spots, in the region B–D, made at Stonyhurst College Observatory, 1882–1889. (Read Dec. 12.)	'Monthly Not. R. A. S. li. 76–78.
	1891.	
J. N. Lockyer .	On the Causes which produce the Phenomena of New Stars. (Read April 16.)	'Phil. Trans.' clxxxii. A 397–448; 'Beiblätter,' xvii. 1067–1068 (Abs.)
	1892.	
W. Sidgreaves .	The bright Solar Prominence of 1891, Sept. 10. (Jan.)	'Astron. and Astrophys.' xi. 66–67.
A. L. Cortie .	The large Sun-spot Group of Aug. 28–Oct. 4, 1891. (Feb.)	'Observatory,' xiv. 363–366; 'Astron. and Astrophys.' xi. 130–133.
W. Sidgreaves .	The Spectrum of Nova Aurigæ. (Read May 13.)	'Mem. R. Astr. Soc. 29–43.
A. L. Cortie . .	Some Recent Studies in the Solar Spectrum. (May.)	'Astron. and Astrophys.' xi. 393–407.
" . .	Notes on the Spectra of Sun-spots. (Aug.)	'Astron. and Astrophys.' xi. 587–593.
W. Sidgreaves .	Nova Aurigæ (Aug.)	'Astron. and Astrophys.' xi. 604–607.
" . .	Report of the Solar Spectroscopic Section of the British Astronomical Association. (Read Oct. 26.)	'Jour. Brit. Astron. Assoc.' iii. 31–35.
" . .	The Nova of 1892. (Oct.)	'Jour. Brit. Astron. Assoc.' iii. 22–24; 'Observatory,' xv. 361–365.
	1893.	
	Errata to 'Note on the Revival of Nova Aurigæ' in 'Astron. and Astrophys.' xi. 883 (note). (July.)	'Astron. and Astrophys.' xii. 560.
A. L. Cortie	The Temporary Star in Auriga. (June.)	'Astron. and Astrophys.' xii. 521–539.

ASTRONOMICAL APPLICATIONS, 1893, 1894, 1896, 1897, 1898.

W. Sidgreaves	The Variable Spectrum of β Lyræ in the region F—b. (Dec.)	'Month. Not. R. A. S.' liv. 94–99.
	The Physical Constitution of the Sun. (Nov.)	'Astron. and Astrophys.' xii. 826–834.
	1894.	
	Notes on Solar Observations at Stonyhurst College Observatory. (Nov.)	'Month. Not. R. A. S.' lv. 6–12.
	1896.	
"	Stellar Spectrum Photography at Stonyhurst. (Lecture Jan. 15.)	'Jour. Brit. Astr. Assoc.' vi. 196–197 (Abs.)
	1897.	
F. McClean	Comparative Photographic Spectra of Stars to the 3½ Magnitude. (Read April 8.)	'Phil. Trans.' cxci. A. 127–138; 'Science Abstr.' ii. 435–436 (Abs.)
W. Sidgreaves	The Spectrum of β Lyræ as observed at Stonyhurst College Observatory in 1895. (May.)	'Month. Not. R. A. S.' lvii. 515–531.
A. Belopolsky	New Researches into the Spectra of β Lyræ and η Aquilæ (in Russian). (Nov.)	'Bull. Acad. St. Petersburg' [5], vii. 355–374; 'Nature,' lxii. 70 (Abs.)
C. G. Abbott	Report of the Work of the Astrophysical Observatory for the year ending June 30, 1897.	'Smithsonian Inst. Rep.' 1897, 66–68.
H. Deslandres	Observation de l'éclipse du soleil du 16 Avril, 1893.	'Ann. du Bureau des Longitudes,' 1897, c. 1–74.
A. C. Maury	Spectra of Bright Stars.	'Annals of Harvard Coll. Obs.' 1897, xxviii. I. ; 'Nature,' lvi. 206–208; 'Naturw. Rundschau,' xii. 581–583.
	1898.	
A. J. Cannon	A Variable Bright Hydrogen Line. (Jan.)	'Harvard Coll. Obs. Circ.' No. 21; 'Nature,' lvii. 284 (Abs.)
E. C. Pickering	A New Spectroscopic Binary. (Jan.)	'Harvard Coll. Obs. Circ.' No. 21; 'Nature,' lvii. 284 (Abs.)
F. McClean	Comparison of Oxygen with the Extra Lines in the Spectra of the Helium Stars β Crucis, &c. Also Summary of the Spectra of Southern Stars to the 3½ Magnitude, and their Distribution. (Read Feb. 3.)	'Proc. Roy. Soc.' lxii. 417–423; 'Astrophys. J.' vii. 367–372; 'Nature,' lvii. 405 (Abs.); 'Science Abstr.' i. 635–636.
	The Total Eclipse of the Sun.	'Nature,' lvii. 265–267.
slandres	Nouvelle série de photographies de la chromosphère entière du soleil. (Read March 21.)	'C. R.' cxxvi. 879–882; 'Science Abstr.' i. 470–471.

ASTRONOMICAL APPLICATIONS, 1898.

Sir J. N. Lockyer	Total Eclipse of the Sun, January 22, 1898. Preliminary Account of the Observations made by the Eclipse Expedition and the Officers and Men of H.M.S. 'Melpomene,' at Viziadrug. (Read March 28.)	'Proc. Roy. Soc.' lxiv. 27–42.
J. Scheiner	On the Spectrum of Hydrogen in the Nebulæ. (April.)	'Astrophys. J.' vii. 231–238; 'Beiblätter,' xxii. 841 (Abs.); 'Science Abstr.' i. 583; 'Nature,' lviii. 41 (Abs.)
W. Sidgreaves	The Spectrum of o Ceti as photographed at Stonyhurst College Observatory. (April.)	'Month. Not. R. A. S.' lviii. 344–353.
A. L. Cortie	On the Level of Sun-spots and the Cause of their Darkness. (April.)	'Astrophys. J.' vii. 239–248.
R. Copeland	Total Solar Eclipse of January 22, 1898. Preliminary Report on Observations made at Ghoglee, Central Provinces. (Read May 10.)	'Proc. Roy. Soc.' lxiv. 21–26.
E. H. Hills and H. F. Newall	Total Solar Eclipse of 1898, January 22. Preliminary Report on the Observations made at Pulgaon, India. (Read May 25.)	'Proc. Roy. Soc.' lxiv. 43–61.
A. L. Cortie	Vanadium in the Spectrum (C—D) of Sun-spots. (May.)	'Month. Not. R. A. S.' lviii. 370–373.
W. H. S. Monck	The Spectra and Proper Motions of Stars. (June.)	'Astrophys. J.' viii. 28–31.
E. C. Pickering	Stars having Peculiar Spectra. (June.)	'Harvard Coll. Obs. Circ.' No. 32; 'Nature,' lviii. 258 (Abs.)
C. Runge	On the Relative Intensities of the Lines in the Spectrum of the Orion Nebula. (June.)	'Astrophys. J.' viii. 32–36; 'Beiblätter,' xxiii. 362–363 (Abs.)
C. L. Poor and S. A. Mitchell	The Concave Grating for Stellar Photography. (June.)	'Astrophys J.' viii. 157–162; 'Science Abstr.' i. 316.
A. J. Cannon	Additional Hydrogen Lines in Stars resembling ζ Puppis. (June.)	'Harvard Coll. Obs. Circ.' No. 32; 'Nature,' lviii. 258 (Abs.)
L. E. Jewell	The Concave Grating for Stellar Photography. (June.)	'Johns Hopkins Univ. Circ.' xvii. 61–62.
J. R. Rydberg	Metargon and the Interplanetary Medium. (July.)	'Nature,' lviii. 319; 'Beiblätter,' xxiii. 395 (Abs.)
A. Belopolsky	Ueber ein Versuch die Geschwindigkeit im Visionsradius der Componenten von γ Virginis und γ Leonis zu bestimmen. (Aug.)	'Astr. Nach.' cl. (No. 3510), 90–94; 'Nature,' lviii. 400–401 (Abs.)
J. E. Keeler	The Hydrogen Atmosphere surrounding the Wolf-Rayet Star D.M. + 30°·3639. (Aug.)	'Astrophys. J.' viii. 113–114; 'Nature,' lviii. 463 (Abs.)

ASTRONOMICAL APPLICATIONS, 1898, 1899.

H. C. Lord	Some Observations on Stellar Motions in the Line of Sight made at the Emerson McMillin Observatory. (Aug.)	'Astrophys. J.' viii. 65-69; 'Beiblätter,' xxiii. 180 (Abs.)
K. D. Nargamvala	Photograph of the Spectrum of the 'Flash' at the Eclipse of Jan. 21, 1898. (Aug.)	'Astrophys. J.' viii. 120-121; 'Nature,' lviii. 526 (Abs.)
	The Nebula of Andromeda. (Sept.)	'Nature,' lviii. 515.
H. Deslandres	Photographie de la vitesse radiale des étoiles. (Sept.)	'Bull. Soc. Astron. de France,' xii. 387-390; 'Nature,' lviii. 490 (Abs.)
Sir J. N. Lockyer	The Chemistry of the Stars. (Inaugural Address, Birmingham and Midland Institute. Oct. 26.)	'Nature,' lix. 32-36; 'Chem. News,' lxxviii. 233-235 (Abs.)
W. W. Campbell	Some Stars with Great Velocities in the Line of Sight. The Variable Velocity of η Pegasi in the Line of Sight. (Oct.)	'Astrophys. J.' viii. 157-160; 'Beiblätter,' xxxiii. 180 (Abs.); 'Nature,' lix. 43 (Abs.)
A. C. Maury	The K-lines of β Aurigæ. (Oct.)	'Astrophys. J.' viii. 173-175; 'Beiblätter,' xxiii. 181 (Abs.)
H. C. Vogel	Ueber das Spectrum von α Aquilæ, und über die Bewegung des Sternes im Visionsradius. (Read Nov. 17.)	'Sitzungsb. Akad. Berlin.' 1898, 721-734; 'Beiblätter,' xxiii. 181 (Abs.); 'Astrophys. J.' ix. 1-15; 'Science Abstr.' ii. 436-437.
Sir J. N. Lockyer	Preliminary Note on the Spectrum of the Corona. (Read Nov. 24.)	'Proc. Roy. Soc.' lxiv. 168-170; 'Nature,' lix. 279-280; 'J. Chem. Soc.' lxxvi. II. 717-718 (Abs.)
Mrs. Fleming	Stars of the Vth Type in the Magellanic Clouds. (Nov.)	'Astrophys. J.' viii. 232; 'Nature,' lix. 330 (Abs.)
"	Classification of Spectra of Variable Stars of Long Period. (Nov.)	'Astrophys. J.' viii. 233; 'Nature,' lix. 330 (Abs.)
G. E. Hale	On the Spectra of Stars of Secchi's Fourth Type. (Nov.)	'Astrophys. J.' viii. 237-238; 'Nature,' lix. 330 (Abs.)
W. W. Campbell	The Variable Velocities of o Leonis and of χ Draconis in the Line of Sight. (Dec.)	'Astrophys. J.' viii. 291-292; 'Beiblätter,' xxiii. 362 (Abs.)
H. Deslandres	Remarques sur les méthodes employées dans la recherche des vitesses radiales des astres. (Dec.)	'Astr. Nachr.' cxlviii. 23-28; 'Astrophys. J.' ix. 167-172; 'Science Abstr. ii. 728.
	Sauerstoff auf der Sonne. Zusammenfassung der Resultate von Runge und Paschen, Janssen, Dunér, Schuster, und Jewell. ('Himmel und Erde,' x. 425.)	'Beiblätter,' xxii. 561-562 (Abs.)

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W. W. Campbell	The Variable Radial Velocity of ζ Geminorum in the Line of Sight. (Jan.)	'Astrophys. J.' ix. 86; 'Nature,' lx. 114 (Abs.)

ASTRONOMICAL APPLICATIONS, 1899.

J. E. Keeler . .	Variation of Spectrum of Orion Nebula. (Jan.)	'Astr. Nachr.' cxlviii. (No. 3541) 207; 'Nature,' lix. 379 (Abs.)
Sir J. N. Lockyer .	Note on the Enhanced Lines in the Spectrum of α Cygni. (Read Feb. 2.)	'Proc. Roy. Soc.' lxiv. 320–322; 'Beiblätter,' xxiii. 361 (Abs.); 'Science Abstr.' ii. 435.
" .	On the Order of Appearance of Chemical Substances at Different Stellar Temperatures. (Read Feb. 23.)	'Proc. Roy. Soc.' lxiv. 396–401; 'Chem. News,' lxxix. 145–147; 'Beiblätter,' xxiii. 792 (Abs.)
A. Mulle . .	Les trois types spectrales des étoiles. (Feb.)	'Rev. Scientifique,' xi. 238–242.
A. Cornu . .	La photographie des spectres d'étoiles. (Read March 1.)	'Bull. Soc. Astron. de France,' Sept. 1899, 379–382.
H. C. Dunér . .	Spectra of Stars of Class III. b. (March.)	'Astrophys. J.' ix. 119–132; 'Nature,' lx. 18 (Abs.)
G. E. Hale . .	The Spectrum of Saturn's Rings. (March.)	'Astrophys. J.' ix. 185–186; 'Nature,' lix. 595 (Abs.)
Mrs. Fleming . .	A New Star in Sagittarius. (March.)	'Harvard Coll. Obs. Circ.' No. 42; 'Nature,' lix. 561 (Abs.)
Sir J. N. Lockyer .	The Chemistry of the Stars in Relation to Temperature. (March.)	'Nature,' lix. 463–466.
" " .	On the Distribution of the various Chemical Groups of Stars. (Lecture to Working Men. April 10.)	'Nature,' lx. 617–620, lxi. 8–11.
	On some Recent Advances in Spectrum Analysis relating to Inorganic and Organic Evolution. (Lecture to Working Men. April 24.)	'Nature,' lx. 103–108.
D. Gill	On the Presence of Oxygen in the Atmospheres of certain Fixed Stars. (Read April 27.)	'Proc. Roy. Soc.' lxv. 196–206; 'Nature,' lx. 190 (Abs.); 'J. Chem. Soc.' lxxvi. II. 718 (Abs.); 'Science Abstr.' ii. 729 (Abs.)
G. E. Hale	Comparison of Stellar Spectra of the Third and Fourth Types. (April.)	'Astrophys. J.' x. 273–274.
	Photographs of the New Star in Sagittarius. (April.)	'Astrophys. J.' ix. 269; 'Nature,' lx. 88 (Abs.)
G. E. Hale	Spectra of Stars of Secchi's Fourth Type. (April.)	'Astrophys. J.' ix. 271–272; 'Nature,' lx. 186–187 (Abs.)
J. Wilsing	Ueber die Deutung des typischen Spectrums der neuen Sterne. (Read May 4.)	'Sitzungsb. Akad. Berlin,' 1899, 426–436; 'Science Abstr.' ii. 728–729; 'Astrophys. J.' x. 113–125.

ASTRONOMICAL APPLICATIONS, 1899.

Sir J. N. Lockyer	On the Chemical Classification of the Stars. (Read May 4.)	'Proc. Roy. Soc.' lxv. 186–191.
A. Belopolsky	Ueber die Bewegung von ζ Geminorum in den Gesichtslinie. (May.)	'Astr. Nachr.' cxlix. (No. 3565) 239; 'Nature,' lx. 114 (Abs.)
G. E. Hale and F. Ellerman.	The Spectra of Stars of Secchi's Fourth Type. (July.)	'Astrophys. J.' x. 87–112; 'Beiblätter,' xxiv. 110–111 (Abs.); 'Nature,' lx. 429 (Abs.)
W. Campbell	New Spectroscopic Multiple Star (Polaris). (Sept.)	'Nature,' lx. 513 (Abs.)
Scheiner	Ueber die photographisch-photometrischen Untersuchungen des Herrn Keeler am Orionnebel. (Oct.) (Reply of J. Keeler, 'Astr. Nachr.' cli. (No. 3601) 3–4.)	'Astr. Nachr.' cl. (No. 3593) 299–302; 'Astrophys. J.' x. 164–168.
W. W. Campbell	The Variable Velocities in the Line of Sight of ε Libræ, λ Draconis, λ Andromedæ, ε Ursæ Minoris, δ Ursæ Minoris, and ω Draconis. (Oct.)	'Astrophys. J.' x. 175–183; 'Nature,' lxi. 114 (Abs.)
W. H. Wright	Observations of Comet Spectra. (Oct.)	'Astrophys. J.' x. 173–176; 'Beiblätter,' xxiv. 481–482 (Abs.)
E. B. Frost	The Variable Velocity of Polaris. (Oct.)	'Astrophys. J.' x. 184–185; 'Nature,' lxi. 114 (Abs.)
W. W. Campbell	The Spectroscopic Binary Capella. (Oct.)	'Astrophys. J.' x. 177; 'Nature,' lxi. 114 (Abs.); Beiblätter,' xxiv. 482 (Abs.)
,,	The Wave-length of the Green Coronal Line, and other Data resulting from an Attempt to Determine the Law of Rotation of the Solar Corona. (Oct.)	'Astrophys. J.' x. 186–192, 306–307; 'Beiblätter,' xxiv. 183 (Abs.); 'Science Abstr.' iii. 176.
A. Belopolsky	Ueber das Spectrum von P Cygni. (Nov.)	'Astr. Nachr.' cli. (No. 3603) 37–40; 'Nature,' lxi. 137 (Abs.)
G. E. Hale	Carbon in the Chromosphere. (Nov.)	'Astrophys. J.' x. 287–288.
Sir J. N. Lockyer	The Piscian Stars. (Read Dec. 14.)	'Proc. Roy. Soc.' lxvi. 126–140; 'Beiblätter,' xxiv. 789–790 (Abs.); 'Nature,' lxi. 213 (Abs.)
J. Lunt	On the Origin of certain Unknown Lines in the Spectra of Stars of the β Crucis Type, and on the Spectrum of Silicon. (Read Dec. 14.)	'Proc. Roy. Soc.' lxvi. 44–50; 'Astrophys. J.' xi. 262–269; 'Beiblätter,' xxiv. 912–913 (Abs.)
A. Belopolsky	Notes on the Spectrum of P Cygni. (Dec.)	'Astrophys. J.' x. 319–321.
J. Fényi	The Great Sun-spot, September 1898. (Dec.)	'Astrophys. J.' x. 333–336; 'Science Abstr.' iii. 300.

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C. A. Young . .	The Wave-length of the Corona Line. (Dec.)	'Astrophys. J.' x. 306–307; 'Beiblätter,' xxiv. 480 (Abs.); 'Science Abstr.' iii. 299–300.
W. Sidgreaves . .	Notes on the Spectra of γ Cassiopeiæ and o Ceti.	'Month. Not. R. A. S.' lix. 502–512.
H. C. Vogel and J. Wilsing . .	Untersuchungen über die Spectra von 528 Sternen. ('Publ. d. Astrophys. Observat. zu Potsdam,' xii. 1. 73 pp.)	
heil.	The Rotation (Observatory.)	
A. Elvins . .	Sun-spot of September and October, 1898. (Proc. Canadian Instit. ii. 35–38.)	'Science Abstr.' iii. 176–177.
C. Dufour . .	Comparaison entre la lumière du soleil et celle de quelques étoiles.	'Arch. de Genève,' viii. 209–217.
C. G. Abbot . .	Report of the Work of the Astrophysical Observatory for the year ending June 30, 1899.	'Smithson. Inst. Report,' 1899; 'Nature,' lxi. 546 (Abs.)

1900.

Sir J. N. Lockyer and A. Fowler.	The Spectrum of α Aquilæ. (Read Feb. 8.)	'Proc. Roy. Soc.' lxvi. 232–238; 'Beiblätter,' xxiv. 995 (Abs.)
A. Belopolsky . .	Ueber eine Methode zur Verstärkung schwacher Linier in Sternspectrogrammen (in Russian.) (Read Feb. 9.)	'Bull. Acad. St. Petersb.' [5], xii. 205–210; 'Beiblätter,' xxv. 131–132 (Abs.)
H. Deslandres .	Variations rapides de la vitesse radiale de l'étoile δ Orionis. (Read Feb. 12.)	'C. R.' cxxx. 379–382; 'Nature,' lxi. 407 (Abs.)
Sir J. N. Lockyer .	Preliminary Note on the Spectrum of the Corona. (Read Feb. 22.)	'Proc. Roy. Soc.' lxvi. 189–192; 'Science Abstr.' iii. 524–525.
H. C. Vogel . .	Ueber die im letzten Decennium in der Bestimmung der Sternbewegung in der Gesichtslinie erreichten Fortschritte. (Read March 29.)	'Sitzungsb. Akad. Berlin,' 1900, 373–390.
W. H. Wright .	The Orbit of the Spectroscopic Binary χ Draconis. (March.)	'Astrophys. J.' xi. 131–134; 'Beiblätter,' xxiv. 996 (Abs.)
K. Schwartzchild .	Ein Verfahren der Bahnbestimmung der spectroscopischen Doppelsternen (March.)	'Astr. Nachr.' clii. (No. 3620) 66–74; 'Nature,' lxi. 521–522 (Abs.)
W. W. Campbell .	The Variable Velocity of β Herculis in the Line of Sight. (March.)	'Astrophys. J.' xi. 140; 'Beiblätter,' xxiv. 790 (Abs.)
Sir J. N. Lockyer .	A Short Account of the Physical Problems now being investigated at the Solar Physics Observatory and their Astronomical Applications. (Phys. Soc. April 27.)	'Nature,' lxii. 23 (Abs.); 'Chem. News,' lxxxi. 214 (Abs.)

ASTRONOMICAL APPLICATIONS, 1900.

L. E. Jewell .	Spectroscopic Determinations of Motion in the Line of Sight, &c. (April.)	'Astrophys. J.' xi. 234–240; 'Science Abstr.' iii. 691.
W. W. Campbell	Some Spectrographic Results obtained at the Indian Eclipse by the Lick Observatory Crocker Expedition. (April.)	'Astrophys. J.' xi. 226–233.
A. Belopolsky	Ein Versuch die Rotationsgeschwindigkeit des Venusæquator auf spectrographischem Wege zu bestimmen. (May.)	'Astr. Nachr.' clii. (No. 3641) 263–276; 'Nature,' lxii. 160–161 (Abs.)
H. Deslandres	Observations de l'éclipse totale du soleil le 28 Mai 1900 à Argamasilla (Espagne). (Read June 18.)	'C. R.' cxxx. 1691–1695; 'Nature,' lxii. 233 (Abs.); 'Astrophys. J.' xii. 287–290; 'Beiblätter,' xxv. 40. (Abs.)
W. H. M. Christie and F. M. Dyson.	Total Eclipse of the Sun, 1900, May 28. Preliminary Account of the Observations made at Ovar, Portugal. (Read June 28.)	'Proc. Roy. Soc.' lxvii. 392–402.
J. Evershed . .	Solar Eclipse of May 28, 1900. Preliminary Report of the Expedition to the South Limit of Totality to obtain Photographs of the Flash Spectrum in High Solar Latitudes. (Read June 28.)	'Proc. Roy. Soc.' lxvii. 370–385.
Sir J. N. Lockyer .	Total Eclipse of the Sun, May 28, 1900. Preliminary Account of the Observations made by the Solar Physics Observatory Eclipse Expedition and the officers and men of H.M.S. 'Theseus' at Santa Pola. (Read June 28.)	'Proc. Roy Soc.' lxvii. 337–346.
H. H. Turner and H. F. Newall.	Total Solar Eclipse of 1900, May 28. Preliminary Report on the Observations made at Bouzareah (in the grounds of the Algiers Observatory). (Read June 28.)	'Proc. Roy. Soc.' lxvi 346–369.
G. Meslin . .	Sur les images spectrales de la chromosphère et des protubérances, obtenues à l'aide de la chambre prismatique. (Read July 30.)	'C. R.' cxxxi. 328–330; 'Beiblätter,' xxiv. 1124–1125 (Abs.).
. Deslandres	Premiers résultats des recherches faites sur la reconnaissance de la couronne solaire avec l'aide des rayons calorifiques. (Read Oct. 15.)	'C. R.' cxxxi. 658–661; 'Nature,' lxiii. 67 (Abs.)
. H. Julius .	Solar Phenomena and Anomalous Dispersion. (Oct.)	'Astrophys. J.' xii. 185–200; 'Science Abstr.' iv. 14.
. de Heen	Constatation de quelques faits relatifs aux stratifications des tubes à vide et au spectre qu'ils présentent. Conjecture sur le mechanisme de ce phénomène. (Read Nov. 3.)	'Bull. Acad. Belg.', 1900, 803–811; 'Beiblätter' xxv. 154 (Abs.)

Sir J. N. Lockyer	On Solar Changes of Temperature and Variations in Rainfall in the Regions surrounding the Indian Ocean. (Read Nov. 22.)	'Proc. Roy. Soc.' lxvii. 409–431.
W. W. Campbell	The Visible Spectrum of Nova Aquilæ. (Nov.)	'Astrophys. J.' xii. 258; 'Beiblätter,' xxv. 41 (Abs.); 'Nature,' lxiii. 260 (Abs.)
E. B. Frost	Spectroscopic Results obtained at the Solar Eclipse of May 28, 1900. (Dec.)	'Astrophys. J.' xii. 307–351; 'Beiblätter,' xxv. 267–268 (Abs.)
W. J. Knight	Can Spectroscopic Analysis furnish us with precise Information as to the Petrography of the Moon? (Dec.)	'Nature,' lxiii. 180.
J. F. Mohler and F. C. Daniel.	The Reversing Layer photographed with a Concave Rowland Grating. (Dec.)	'Astrophys. J.' xii. 361–365; 'Beiblätter,' xxv. 268–269 (Abs.)
J. Wilsing	Untersuchungen über das Spectrum des Nova Aurigæ. ('Publ. d. Astrophys. Observat. zu Potsdam,' xii. 77–102.)	'Beiblätter,' xxiv. 995–996 (Abs.)
A. Berberich	Die Sonnencorona. ('Naturw. Rundschau,' xv. 29–30.)	'Beiblätter,' xxiv. 480 (Abs.)
J. Hartmann	Anwendung der Photographie zur spectralphotometrischen Messung der Helligkeit von Himmelskörpern. ('Jahrb. f. Photogr.' 1900, 240–244.)	

VII.

METEOROLOGICAL APPLICATIONS.

1898.

E. C. Pickering	The Photographic Spectrum of the Aurora. (May.)	'Harvard Coll. Obs. Circ.' No. 28; 'Astrophys [illegible] vii. 392; 'Beiblätter,' [illegible] 843 (Abs.); 'Na[illegible] lvii. 591 (Abs.)
A. Schuster	The Origin of the Aurora Spectrum. (June.)	'Nature,' lviii. 15[illegible]
Sir W. Crookes	Helium in the Atmosphere. (Oct.)	'Chem. News,' lx[illegible] 'Beiblätter,' x[illegible] (Abs.)
T. W. Backhouse	The Origin of the Aurora Spectrum. (Nov.)	'Nature,' lix. 127.
C. Runge	The Origin of the Aurora Spectrum. (Nov.)	'Nature,' lix. 29.

1899.

A. de la Baume Pluvinel.	Observation du groupe des raies B du spectre solaire faite au sommet du Mont Blanc. (Read Jan. 30.)	'C. R.' cxxviii. 260[illegible] 'Beiblätter,' xxiii.[illegible] (Abs.); 'Science A[illegible] ii. 437–438; 'Na[illegible] lix. 359 (Abs.)

METEOROLOGICAL APPLICATIONS, 1899.—CHEMICAL RELATIONS, 1896, 1897.

B. Hasselberg .	Note sur la diffusion cosmique de vanadium.	'Mem. Soc. Spettr. Ital.' xxviii. 113-119; 'Nature,' lx. 487 (Abs.)
Paulsen . .	Sur le spectre des aurores polaires. (Read March 5.)	'C. R.' cxxx. 655-656; 'Beiblätter,' xxiv. 479-480 (Abs.); 'Nature,' lxi. 621 (Abs.)

VIII.

CHEMICAL RELATIONS.

1896.

B. Hasselberg .	Ueber das Vorkommen des Vanads in den Scandinavischen Rutilarten. (Read Dec. 9.)	'Bihang till K. Vet. Akad. Handl.' xxii. Afd. i. No. 7, 7 pp.; 'Zeitschr. f. anorg. Chem.' xviii. 85 (Abs.); 'Chem. Centr.' 1898, II. 1068 (Abs.); 'Chem. News,' lxxvi. 112-113.

1897.

Wróblewski .	Anwendung des Glan'schen Spektrophotometers auf die Thierchemie. I. Quantitative Bestimmung des Oxyhæmoglobin im Blute. II. Quantitative Bestimmung der Rhodansalze im Speichel.	'C. R. de l'Acad. des Sci. de Cracovie,' 1896, 386-390; 'Chem. Centr.' 1897, II. 532 (Abs.); 'J. Chem. Soc.' lxxiv. II. 415 (Abs.)
B. Hasselberg .	Zur chemischen Constitution des Rutils. (Read March 10.)	'Bihang till K. Vet. Akad. Handl.' xxiii. Afd. i. No. 3, 8 pp.; 'Zeitschr. f. anorg. Chem.' xviii. 85 (Abs.); 'Chem. Centr.' 1898, II. 1068 (Abs.)
G. Abati . .	Sul potere rifrangente e dispersivo del silicio nei suoi composti. (Read June 12.)	'Gazz. chim. Ital.' xxvii II. 437-455; 'Beiblätter,' xxii. 557 (Abs.); 'J. Chem. Soc.' lxxiv. II. 274 (Abs.)
: .	Note on the Chemical Composition of the Mineral Rutile. (June.)	'Astrophys. J.' vi. 22-26; 'Chem. News,' lxxvi. 102-104.
t .	Observations sur les spectres des composés. (Read July 23.)	'Bull. Soc. Chim.' [3] xvii. 774-778; 'Chem. News,' lxxvi. 277 (Abs.); 'J. Chem. Soc.' lxxvi. II. 197-198 (Abs.)
.	Spectres de dissociation des sels fondus. Métaux alcalins, sodium, lithium, potassium. (Read July 23.)	'Bull. Soc. Chim.' [3] xvii. 778-782; 'Chem. News,' lxxvi. 244-246; 'J. Chem. Soc.' lxxvi. II. 198 (Abs.)
	Spectres de dissociation des sels fondus; métalloïdes, chlore, brome, iode. (July.)	'Bull. Soc. Chim.' [3] xvii. 897-901; 'Chem. News,' lxxviii. 28-29; 'Science Abstr.' i. 247-248.
' and	The Spectrographic Analysis of Minerals and Meteorites. (Aug.)	'Brit. Assoc. Report,' 1897 610 (Abs.); 'Chem. News,' lxxvi. 231 (Abs.)

CHEMICAL RELATIONS, 1897, 1898.

C. Runge and F. Paschen.	Ueber die Serienspectra der Elemente, Sauerstoff, Schwefel und Selen. (Aug.)	'Ann. Phys. u. Chem. [N.F.], lxi. 641-686 'Brit. Assoc. Rep.' 1897 555; 'Chem. News,' lxxvi 255-256.
F. Kehrmann .	Ueber die Constitution der Oxazin-Farbstoffe und den vierwerthigen Sauerstoff. (Read Oct. 9.)	'Ber.' xxxii. 2601-2611.
A. de Gramont .	Dissociation Spectra of some Fused Salts. (Oct.)	'Chem. News,' lxxvi. 201-204.
H. Kayser . .	Ueber die Spectren der Elemente der Platingruppe. (Read Dec. 2.)	'Abhandl. Akad. Berl. 1897, 44 pp.; 'Beiblätter, xxii. 667 (Abs.)
A. de Gramont	Spectres de dissociation des sels fondus; soufre, phosphore, composés phosphoreux solides. (Read Dec. 24.)	'Bull. Soc. Chim.' [3], xix 54-59; 'J. Chem. Soc. lxxvi. II. 345 (Abs.)

1898.

W. Ramsay and M. W. Travers.	The Companions of Argon. (Read Jan. 29.)	'Proc. Roy. Soc.' lxiii 437-440; 'Science Abstr. i. 718 (Abs.); 'Beiblätter, xxii. 513-514 (Abs.) 'Zeitschr. f. physikal Chem.' xxvi. 564-567 (Abs.)
	The Homogeneity of Helium. (Read Jan. 29.)	'Proc. Roy. Soc.' lxii 316-324; 'Chem. News, lxxvii. 61-64; 'Chem. Centr.' 1898, I. 707 (Abs.)
J. Werder	Das Refractometer in der Wachsuntersuchung. (Jan.)	'Chem. Zeitung,' xxii. 38, 59; 'Chem. Centr.' 1898, I. 477, 531-532 (Abs.)
J. J. Dobbie and F. Marsden.	Preparation and Properties of Orthochlorobromobenzene. (Read Feb. 17.)	'J. Chem. Soc.' lxxiii. 254-255; 'Chem. Centr.' 1898, I. 1103 (Abs.)
P. Schutzenberger and O. Boudouard.	Sur les terres yttriques contenues dans les sables monazités. (Read Feb. 25.)	'Bull. Soc. Chim.' [3], xix. 227-244.
J. Thomsen	Ueber Abtrennung von Helium aus einer natürlichen Verbindung unter starkes Licht und Wärmentwickelung. (Feb.)	'Zeitschr. f. physikal. Chem.' xxv. 112-114; 'Chem. Centr.' 1898, I. 656-657.
B. Brauner . .	On Praseodidymium and Neodidymium. (Read March 17.)	'Proc. Chem. Soc.' xiv. 70-72; 'Chem. Centr.' 1898, I. 919-920.
A. Boudouard .	Sur la néodyme. (Read March 21.)	'C. R.' cxxvi. 900-901; 'J. Chem. Soc.' lxxiv. II. 518 (Abs.)
G. Urbain . .	Sur la nature du didyme qui accompagne l'yttria provenant des sables monazités. (Read March 25.)	'Bull. Soc. Chim.' [3], xix. 381-382; 'Chem. News,' lxxviii. 74; 'J. Chem. Soc.' lxxvi. II. 424-425 (Abs.)

CHEMICAL RELATIONS, 1898.

A. de Gramont .	Analyse spectrale des composés non conducteurs par les sels fondus. (Read April 18.)	'C. R.' cxxvi. 1155–1157; 'Nature,' lvii. 624 (Abs.); 'Chem. News,' lxxvii. 118–119.
J. W. Brühl . .	Spectrochemie des Stickstoffs. VI. (Read May 12.)	'Zeitschr. f. physikal. Chem.' xxv. 577–650; 'Ber.' xxxi. 1350–1370; 'J. Chem. Soc.' lxxiv. II. 362–363 (Abs.); 'Chem. News,' lxxix. 202 (Abs.)
A. de Gramont .	Analyse spectrale de quelques minéraux non conducteurs par les sels fondus et réactions des éléments. (Read May 23.)	'C. R.' cxxvi. 1513–1515; 'J. Chem. Soc.' lxxiv. II. 635–636 (Abs.); 'Chem. News,' lxxviii. 2–3.
J. W. Brühl .	Spectrochemie des Stickstoffs; VII. Sauerstoffverbindungen des Stickstoffs im gelöstem Zustande. (Read May 23.)	'Zeitschr. f. physikal. Chem.' xxvi. 47–76; 'Ber.' xxxi. 1465–1477; 'Beiblätter,' xxii. 661–662 (Abs.); 'J. Chem. Soc.' lxxiv. II. 417–418 (Abs.); 'Chem. News,' lxxix. 215 (Abs.)
F. Krüger	Die Bestimmung des Hämoglobin im Katzenblute. (May.)	'Zeitschr. f. physiol. Chem.' xxv. 256–257; 'Chem. Centr.' 1898, II. 494 (Abs.)
W. Ramsay and M. W. Travers.	Sur un nouvel élément, constituant de l'air atmosphérique. (Read June 6.)	'C. R.' cxxvi. 1610–1613; 'Chem. Centr.' 1898, II. 81 (Abs.); 'Chem. News,' lxxvii. 270 (Abs.); 'Nature,' lviii. 167 (Abs.)
A. Boudouard	Sur les terres yttriques contenues dans les sables monazités. (Read June 6.)	'C. R.' cxxvi. 1648–1651; 'J. Chem. Soc.' lxxiv. II. 587 (Abs.); 'Chem. News,' lxxviii. 28.
Sir W. Crookes .	On the Position of Helium, Argon, and Krypton in the System of Elements. (Read June 9.)	'Proc. Roy. Soc.' lxiii. 408–411; 'Zeitschr. f anorg. Chem.' xviii. 72–76.
W. Ramsay and M. W. Travers.	On a New Constituent of Atmospheric Air. [Krypton.] (Read June 9.)	'Proc. Roy. Soc.' lxiii. 405–408; 'C. R.' cxxvi. 1610–1613; 'J. de Phys.' [3], vii. 393–396; 'Beiblätter,' xxii. 513–514 (Abs.)
A. de Gramont	Spectres de dissociation des sels fondus; metalloïdes, carbone. (Read June 10.)	'Bull. Soc. Chim.' [3] xix. 548–550; 'Chem. News,' lxxviii. 270–271.
	Spectres de dissociation des sels fondus; metalloïdes, silicium. (Read June 10.)	'Bull. Soc. Chim.' [3], xix. 551; 'Chem. News,' lxxviii. 258 (Abs.)
W. Ramsay and M. W. Travers.	Nouveaux gaz de l'air atmosphérique. [Néon.] (Read June 20.)	'C. R.' cxxvi. 1762–1763; 'Chem. Centr.' 1898, II. 81 (Abs.); 'J. Chem. Soc.' lxxiv. II. 574 (Abs.)

CHEMICAL RELATIONS, 1898.

G. Urbain.	Sur les terres yttriques provenant des sables monazités. (Read July 11.)	'C. R.' cxxvii. 107-108; 'Chem. Centr.' 1898, II. 408 (Abs.); 'Chem. News,' lxxviii. 61.
A. de Gramont	Analyse spectrale des corps non-conducteurs par les sels fondus. (Read July 22.)	'Bull. Soc. Chim.' [3], xix. 742-746; 'Chem. Centr.' 1898, II. 788 (Abs.)
R. Nasini, F. Anderlini, and R. Salvadori.	Sulla probabile presenza del coronio e di nuovi elementi nei gas della Solfatara di Possuoli e del Vesuvio. (Read Aug. 7.)	'Atti R. Accad. d. Lincei' [5], vii. 73-74; 'Chem. Centr.' 1898, II. 617 (Abs.); 'J. Chem. Soc.' lxxvi. II. 482-483 (Abs.)
J. Dewar . .	Metargon. (Aug.)	'Nature,' lviii. 319; 'Beiblätter,' xxiii. 395 (Abs.)
O. Neovius . .	Ueber das vermuthliche Vorkommen eines bis jetzt unbekannten Stoffes in der Atmosphäre. (Sept.)	'Ann. Phys. u. Chem.' [N.F.], lxvi. 162-169; 'Chem. Centr.' 1898, II. 252 (Abs.); 'Science Abstr.' ii. 52; 'Nature,' lix. 46 (Abs.)
W. Ramsay and M. W. Travers.	On the Extraction from Air of the Co[illegible]ions of Argon, and on [illegible] (Sept.)	'Brit. Assoc. Report,' 1898, 828-830; 'Chem. News,' lxxviii. 154-155; 'Chem. Centr.' 1898, II. 852-853 (Abs.)
A. de Gramont	[illegible]ns sur quelques spectres; [illegible]a, tellure, sélénium. [illegible]ov. 28.)	'C. R.' cxxvii. 866-868; 'Chem. Centr.' 1899, I. 14 (Abs.); 'J. Chem. Soc.' lxxvi. II. 199 (Abs.); 'Chem. News,' lxxix. 35 (Abs.)
H. R. Procter. .	The Refractive Constant in Oil and fat analysis. (Nov.)	'J. Soc. Chem. Ind.' xvii. 1021-1025; 'J. Chem. Soc.' lxxvi. II. 258 (Abs.); 'Chem. Centr.' 1899, I. 233-234 (Abs.)
W. Ramsay and M. W. Travers.	The Preparation and some of the Properties of Pure Argon. (Read [illegible] 15.)	'Proc. Roy. Soc.' lxiv. 183-192; 'Chem. News,' lxxix. 49-50; 'Zeitschr. f. physikal. Chem.' 241-250.
W. Ramsay . .	Ueber die neuerdings entdeckten Gase und der Beziehung zum periodischen Gesetz. (Read Dec. 19.)	'Ber.' xxxi. 3111-3121; 'Chem. Centr.' 1899, I. 323-324 (Abs.); 'J. Chem. Soc.' lxxvi. II. 211-212 (Abs.); 'Science Abstr.' ii. 370-371.
E. Riegler . .	Eine neue Methode zur Bestimmung der Phosphorsäure auf refractometrischem Wege. ('Buletinul Soc. Sci. Bucarest,' vii. 172-174.)	'Chem. Centr.' 1898, II. 313-314 (Abs.)
A. J. Swaving	Ueber die praktische Verwendung des Refractometers für die Butteruntersuchung. ('Landw. Ver. Stat.' xlix. 341-347.)	'Chem. Centr.' 1898, I. 352 (Abs.)

CHEMICAL RELATIONS, 1898, 1899.

H. Zikes	Refractometrische Bieranalyse nach Herkules Tornoe. ('Oesterr. Chem. Zeitung,' i. 7–9.)	'Chem. Centr.' 1898, I 1311 (Abs.)

1899.

Sir J. Conroy	On the Refractive Indices and Densities of Normal and Semi-normal Solutions of Hydrogen Chloride and the Chlorides of the Alkalis. (Read Jan. 19.)	'Proc. Roy. Soc.' lxiv. 308–318.
A. Nabl	Ueber farbende Bestandtheile des Amethysten, Citrins, und gebrannten Amethysten. (Read Feb. 3.)	'Monatsh. f. Chem.' xx. 272–281; 'J. Chem. Soc.' lxxvi. 11. 561 (Abs.)
B. Hasselberg	Note sur la diffusion cosmique de vanadium. (Read March 8.)	'Oefvers. K. Svenska Vet. Akad. Förhandl.' lvi. 131–140; 'J. Chem. Soc.' lxxx. II. 251. (Abs.)
M. Wager	Oel- und Firnisanalyse mittels Refractometers. (March.)	'Zeitschr. f. angew. Chem.' 1899, 297–300; 'Chem. Centr.' 1899, I. 1004–1005 (Abs.)
W. N. Hartley and H. Ramage.	A Spectrographic Analysis of Iron Meteorites, Siderolites, and Meteoric Stones. (April.)	'Astrophys. J.' ix. 221–228.
Sir J. N. Lockyer	The Present Standpoint in Spectrum Analysis. (April.)	'Nature,' lix. 585–588.
W. Hallwachs	Ueber ein Doppelrefractometer und Untersuchungen mit demselben an Lösungen von Bromcadmium, Zucker, Di- und Trichloressigsäure, sowie deren Kaliumsalze. (May.)	'Ann. Phys. u. Chem.' [N.F.], lxviii. 1–4; 'J. Chem. Soc.' lxxvi. II. 461–462 (Abs.); 'Science Abstr.' ii. 597.
R. T. Günther and J. J. Manley.	On the Waters of the Salt Lake of Urmi. (Read June 15.)	'Proc. Roy. Soc.' lxv. 312–318; 'Nature,' lx. 359–360 (Abs.)
M. Berthelot	Nouvelles recherches sur l'argon et ses combinaisons. (Read July 10.)	'C. R.' cxxix. 71–84; 'Nature,' lx. 288 (Abs.)
P. Lewis	Ueber den Einfluss kleiner Beimengungen zu einem Gase auf dessen Spectrum. (July.)	'Ann. Phys. u. Chem.' [N.F.], lxix. 398–425; 'Astrophys. J.' x. 137–163; 'Science Abstr.' iii. 181.
C. Benedicks	Beiträge zur Kenntnis des Gadoliniums. (Sept.)	'Zeitschr. f. anorg. Chem.' xxii. 393–421; 'Chem. News,' lxxxi. 51–53, 62–63, 77–78.
J. B. Frankforter and E. P. Harding.	A Chemical Study of Wheat. (Sept.)	'J. Amer. Chem. Soc.' xxi. 758–769; 'J. Chem. Soc.' lxxviii. II. 37 (Abs.)
A. Chilesotti	Sul potere rifrangente di alcuni idrocarburi a nuclei benzolici condensati. (Read Nov. 14.)	'Gazz. chim. Ital.' xxx. I. 149–169; 'Chem. Centr.' 1900, I. 797 (Abs.)
Sir J. N. Lockyer	The Methods of Inorganic Evolution. (Nov.)	'Nature,' lxi. 129–131.

CHEMICAL RELATIONS, 1899, 1900.

A. Haller and P. M. Müller.	Sur les réfractions moléculaires, la dispersion moléculaire, et le pouvoir rotatoire de quelques alcoylcamphres. (Read Dec. 11.)	'C. R.' cxxix. 1005–1008; 'Beiblätter,' xxiv. 448 (Abs.); 'J. Chem. Soc.' lxxviii. I. 182 (Abs.)
F. Stolle	Untersuchungen über Karamelkörper. II. Quantitative Bestimmung des Karamels in wasserigen Lösungen mittels des Spectroscops.	'Zeitschr. ver. Rübenzucker-Industr.' xlix. 839–842; 'Chem. Centr.' 1899, II. 1099 (Abs.); 'J. Chem. Soc.' lxxviii. II. 249–250 (Abs.)
J. Formánek.	Ueber den spectroscopischen Nachweis der organischen Farbstoffe ('Z. Unters. Nahr.-Genus.' ii. 260–273.)	'Chem. Centr.' 1899, I. 947 (Abs.)
V. Arnold	Ein Beitrag zur Spectroscopie des Blutes ('Centralbl. f. med. Wiss.' xxxvii. 465–468.)	'Chem. Centr.' 1899, II. 344 (Abs.)

1900.

S. Young and Emily C. Fortey.	Note on the Refraction and Magnetic Rotation of Hexamethylene. (Read Feb. 15.)	'J. Chem. Soc.' lxxvii. 372–374; 'Proc. Chem. Soc.' xvi. 44 (Abs.)
W. N. Hartley and J. J. Dobbie.	Spectrographic Studies in Tautomerism. The Absorption Curves of the Ethyl Esters of Dibenzoylsuccinic Acid. (Read March 1.)	'J. Chem. Soc.' lxxvii. 498–512; 'Proc. Chem. Soc.' xvi. 57–58 (Abs.); 'Chem. News,' lxxxi. 141 (Abs.)
A. Ladenberg and C. Krügel.	Ueber das Krypton. (March.)	'Sitzungsb. Akad. Berlin,' 1900, 212–217; 'J. Chem. Soc.' lxxviii. II. 540 (Abs.)
E. Demarçay.	Sur le Samarium. (Read April 30.)	'C. R.' cxxx. 1185–1186; 'Chem. Centr.' 1900, I. 1199–1200 (Abs.); 'Chem. News,' lxxxi. 251 (Abs.); 'J. Chem. Soc.' lxxviii. II. 469 (Abs.)
J. Formánek.	Ueber Acetophenon Azobilirubin. (April.)	'Zeitschr. f. physiol. Chem.' xxix. 411–415; 'Chem. Centr.' 1900, II. 129 (Abs.)
Sir J. N. Lockyer.	On the Chemical Classification of the Stars. (Read May 4.)	'Proc. Roy. Soc.' lxv. 186–191; 'Nature,' lx. 52–54; 'J. Chem. Soc.' lxxvi. II. 718 (Abs.)
E. Demarçay	Sur les terres inconnues contenues dans la samarine brute. (Read May 28.)	'C. R.' cxxx. 1469–1472; 'Chem. Centr.' 1900, II. 19–20 (Abs.); 'Chem. News,' lxxxi. 311 (Abs.)
G. v. Georgievics and E. Valenta.	Ueber die Azofarbstoffe aus β-naphtol und den Monosulfosäuren des α-naphtylamins. (Read June 15.)	'Monatsh. f. Chem.' xxi. 831–844; 'Chem. Centr.' 1901, I. 222 (Abs.); 'Beiblätter,' xxv. 194 (Abs.)
E. Demarçay.	Sur le gadolinium. (Read July 30.)	'C. R.' cxxxi. 343–345; 'J. Chem. Soc.' lxxviii. II. 597–598 (Abs.)

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P. Lewis	Ueber den Einfluss kleiner Beimengungen zu einem Gase auf dessen Spectrum. II. Abth. (July).	'Ann. der Phys.'[4] i. 447–458; 'Nature,' lxii. 381 (Abs.); 'Astrophys. J.' xii. 16–23; 'J. Chem. Soc.' lxxviii. I. 701 (Abs.)
C. Rivière	Indice de réfraction et dispersion du brome. (Read Oct. 22.)	'C. R.' cxxxi. 671–672; 'Nature,' lxiii. 24 (Abs.)
W. Ramsay and M. W. Travers .	Argon and its Companions. (Read Nov. 15.)	'Proc. Roy. Soc.' lxvii. 329–333; 'Nature,' lxiii. 165; 'Chem. News,' lxxxii. 257–258.
W. N. Hartley and H. Ramage. .	On a Simplified Method for the Spectrographic Analysis of Minerals. (Read Nov. 15.)	'J. Chem. Soc.' lxxix. 61–71; 'Proc. Chem. Soc.' xvi. 191 (Abs.); 'Chem. News,' lxxxii. 277 (Abs.)
W. Muthmann and L. Stützel . .	Beiträge zu Spectralanalyse von Praseodym. (Nov.)	'Ber.' xxxiii. 2653–2674; 'Chem. News,' lxxxii. 282 (Abs.)
F. Emich . .	Zur Empfindlichkeit der Spectralreactionen. ('Wien. Anz.' 1900, 78.)	'Beiblätter,' xxiv. 471 (Abs.)
K. Ibsen . .	Ein weiterer Beitrag zum spectralen Blutnachweis. ('Vierteljahrb. f. ges. Med.' xix. 1–9.)	'Chem. Centr.' 1900, i. 688–689.
G. Hüfner . .	Ueber die gleichseitige Bestimmung zweier Farbstoffe im Blute mit Hülfe des Spectrophotometer. ('Arch. f. Physiol.' 1900, 39–48.)	'Chem. Centr.' 1900, i. 512–513 (Abs.); 'J. Chem. Soc.' lxxviii. II. 459 (Abs.)
J. A. Grober . .	Quantitativen Zuckerbestimmungen mit dem Eintauschrefractometer. ('Centralbl. f. inn. Med.' xxi. 201–247.)	'Chem. Centr.' 1900, i. 626–627 (Abs.)

IX.

THEORETICAL PAPERS.

1897.

G. F. FitzGerald .	Zeeman's Phenomenon. (Sept.)	'Nature,' lvi. 468.
A. Cornu . .	Sur l'observation et l'interprétation cinématique des phénomènes découvertes par M. le Dr. Zeeman. (Read Nov. 5.)	'Séances de la Soc. Franç. de Phys.' 1897, 138–143.
H. A. Lorentz .	Ueber den Einfluss magnetischer Kräfte auf die Emission des Lichtes. (Dec.)	'Ann. Phys. u. Chem.' [N.F.], lxiii. 278–284; 'Science Abstr.' i. 387–388

1898.

P. Drude	Die optische Constanten des Natriums. (Feb.)	'Ann. Phys. u. Chem.' [N.F.], lxiv. 159–162; 'Nature,' lvii. 500 (Abs.)
A. Schuster .	Prof. C. Runge and F. Paschen's Researches on the Spectra of Oxygen, Sulphur, and Selenium. (Feb.)	'Nature,' lvii. 320–321; 'Ann. Phys. u. Chem.' [N.F.], lxi. 641; 'Beiblätter' xxii. 400 (Abs.)

THEORETICAL PAPERS, 1898.

G. F. FitzGerald	Note on the Connection between the Faraday Rotation of Plane of Polarisation and the Zeeman Change of Frequency of Light Vibrations in a Magnetic Field. (Read March 10.)	'Proc. Roy. Soc.' lxiii. 31–35; 'Science Abstr.' i. 386–387; 'Beiblätter,' xxii. 869–870 (Abs.)
A. Pflüger	Prüfung der Ketteler-Helmholtz'schen Dispersionsformeln an den optischen Constanten anomaldispergirender fester Farbstoffe. (April.)	'Ann. Phys. u. Chem.' [N.F.], lxv. 173–213; 'Science Abstr.' i. 637–638.
	Nachtrag zu der Abhandlung 'Prüfung der Ketteler-Helmholtz'schen Dispersionsformeln an den optischen Constanten anomal-dispergirender fester Farbstoffe.' (April.)	'Ann. Phys. u. Chem.' [N.F.], lxv. 225–228.
	Prüfung der Cauchy'schen Formeln der Metallreflexion und den optischen Constanten des festen Cyanins. (April.)	'Ann. Phys. u. Chem.' [N.F.], lxv. 214–224; 'Science Abstr.' i. 639 (Abs.)
J. G. Leathem	On the Possibility of Deducing Magneto-optic Phenomena from a Direct Modification of an Electrodynamic Energy Function. (Read May 16.)	'Trans. Phil. Soc. Camb.' xvii. 16–40; 'Proc. Phil. Soc. Camb.' ix. 530–531 (Abs.); 'Beiblätter,' xxiii. 257–258 (Abs.)
J. Wilsing	Theoretical Considerations respecting the Dependence of Wavelength on Pressure which Messrs. Humphreys and Mohler have observed in the Arc Spectra of certain Elements. (May.)	'Astrophys. J.' vii. 317–329; 'Beiblätter,' xxii. 558–559 (Abs.); 'Science Abstr.' i. 639–640.
A. Righi	Sulla interpretazione cinematica del fenomeno di Zeeman. (Read June 11.)	'Rend. R. Accad. d. Lince' [5], vii. I. 295–301; 'Science Abstr.' ii. 165–167.
H. A. Lorentz	Beschouwingen over den Invloed van een magnetisch Veld op de Uitstraling van Licht. (Read June 25.)	'Zittingsversl. R. Akad. Amsterdam,' 1898–9, Deel, vii. 113–122; 'Nature,' lviii. 360 (Abs.)
S. A Mitchell	Notes on the Concave Grating. (June.)	'Johns Hopkins Univ. Circ.' xvii. 56–58; 'Astrophys. J.' viii. 102–112.
Lord Kelvin	The Dynamical Theory of Refraction and Anomalous Dispersion. (Sept.)	'Brit. Assoc. Report,' 1898, 782–783.
C. A. Mebius	Om B. Galitzin's teorie för spectralliniernas utbredning. (Read Oct. 12.)	'Oefvers. af. K. Vet. Acad. Förh.' lv. 485–495; 'Beiblätter,' xxiii. 419–420 (Abs.)
W. Voigt	Zur Theorie der von den Herren Macaluso und Corbino entdeckten Erscheinungen. (Read Nov. 26.)	'Gött. Nachr.' 1898, IV. 349–354.
A. Bovida	La luce monocromatica come vibrazione ammortita. (Nov.)	'Rivista scientifica,' xxx. 225–236; 'Science Abstr.' ii. 599–600.

THEORETICAL PAPERS, 1898.

R. v. Kövesligethy	Der beiden Parametergleichungen der Spectralanalyse.	'Math. u. naturwiss. Ber. aus Ungarn,' xvi. 1–50; 'Beiblätter,' xxiv. 1280–1281 (Abs.)
J. Hartmann .	Ueber ein einfache Interpolationsformel für das prismatische Spectrum. ('Publ. d. Astrophys. Observat. zu Potsdam,' xii. 25 pp.)	'Astrophys. J.' viii. 218–222.
Ch. Fabry and A. Perot.	Théorie et applications d'une nouvelle méthode de spectroscopie interférentielle. (Jan.)	'Ann. Chim. et Phys.' [7], xvi. 115–144; 'Beiblätter,' xxiv. 178–180 (Abs.)
D. Macaluso and O. M. Corbino.	Sulla relazione tra il fenomeno di Zeeman e la rotazione magnetica anomala del piano de polarizzazione della luce. (Read Feb. 5.)	'Rend. R. Accad. d. Lincei' [5], viii. I. 116–121; 'Il Nuovo Cimento' [4], ix. 384–389.
A. Cotton . .	L'aspect actuel de la loi de Kirchhoff. (Feb.)	'Rev. gén. des Sciences,' x. 102–115.
Lord Kelvin . .	Application of Sellmeier's Dynamical Theory to the Dark Lines, D_1, D_2, produced by Sodium Vapour. (Feb.)	'Phil. Mag.' [5], xlvii. 302–308; 'Science Abstr.' ii. 638; 'Astrophys. J.' ix. 231–236.
O. M. Corbino .	Sulla dipendenza tra il fenomeno di Zeeman e le altri modificazioni che la luce subisce dai vapori metallici in un campo magnetico. (Read March 5.)	'Atti R. Accad. d. Lincei' [5], viii. I. 250–254; 'Science Abstr.' ii. 661–662.
J. Larmor . .	On the Origin of Magneto-optic Rotation. (Read March 6.)	'Proc. Phil. Soc. Camb.' x. 181–182; 'Nature,' lix. 527 (Abs.)
F. Schlesinger .	Reduction to the Sun of Observations for Motion in the Line of Sight. (Feb.)	'Astrophys. J.' ix. 159–161; 'Science Abstr.' ii. 728.
H. Poincaré . .	La théorie de Lorentz et le phénomène de Zeeman. (April.)	'L'Éclairage électrique,' xix. 5–15; 'Science Abstr.' ii. 737.
H. Veillon	Elementare geometrische Behandlung des Minimums der Ablenkung beim Prisma. (May.)	'Zeitschr. f. phys. u. chem. Unterr.' xii. 150–152; 'Beiblätter,' xxii. 552 (Abs.)
W. Voigt . .	Weiteres zur Theorie des Zeemaneffectes. (June.)	'Ann. Phys. u. Chem.' [N.F.], lxviii. 352–364; 'Science Abstr.' ii. 662.
	Zur Erklärung der unter gewissen Umständen eintretenden Verbreiterung und Umkehrung der Spectrallinien. (July.)	'Ann. Phys. u. Chem.' [N.F.], lxviii. 604–606; 'Science Abstr.' ii. 737–738.
Lord Rayleigh .	The Theory of Anomalous Dispersion. (July.)	'Phil. Mag.' [5], xlviii. 151–152; 'Beiblätter,' xxiii. 983 (Abs.)
W. Voigt	Bemerkung über die bei dem Zeeman'schen Phänomen stattfindenden Intensitätsverhältnisse. (Sept.)	'Ann. Phys. u. Chem.' [N.F.], lxix. 290–296; 'Science Abstr.' ii. 822 (Abs.)

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H. A. Lorentz . .	Zur Theorie des Zeemaneffectes. (Oct.)	'Phys. Zeitschr.' i. 39-41; 'Beiblätter,' xxiv. 930-931 (Abs.)
W. A. Michelson .	Zur Frage über die richtige Anwendung des Doppler'schen Prinzips. (In Russian.)	'J. Russ. Phys. Chem. Soc.' xxxi. 119-125; 'Beiblätter,' xxiv. 251-253 (Abs.)

1900.

A. de Gramont .	Sur quelques conséquences des formulas du prisme. (Read Feb. 12.)	'C. R.' cxxx. 403-406; 'Beiblätter,' xxiv. 450 (Abs.)
E. Riecke . .	Zur kinetik der Serienschwingungen eines Linienspectrums. (Feb.)	'Ann. der Phys.' [4] i. 399-413; 'Science Abstr.' iii. 308; 'Physikal. Zeitschr.' ii. 107-108.
W. W. Campbell .	The Determination of the Moon's Theoretical Spectrographic Velocity. (March.)	'Astrophys. J.' xi. 141 142; 'Beiblätter,' xxiv. 784, 785 (Abs.)
H. Lehmann . .	Ueber Spectralapparate mit drehbarem Gitter. (July.)	'Zeitschr. f. Instrumentenkunde,' xx. 193-204.
E. V. Capps . .	Bestimmung des Spaltwerthes für spectrophotometrische Messungen. (Sept.)	'Physikal. Zeitschr.' i. 558-560.
M. Planck . .	Ueber eine Verbesserung der Wien'schen Spectralgleichung. (Read Oct. 19.)	'Verh. Deutsch. phys. Gesellsch.' [2], ii. 202-204.
,, . .	Zur Theorie des Gesetzes der Energievertheilung im Normalspectrum. (Read Dec. 14.)	'Verh. Deutsch. phys. Gesellsch.' [2], ii. 237-245; 'Science Abstr.' iv. 230.
G. J. W. Bremer .	Indices de réfraction des solutions du chlorure de calcium.	'Arch. néerland.' [2], v. 208-213; 'Science Abstr.' iv. 363.
C. Viola . .	Le deviazioni minime della luce mediante prismi di sostanze anisotrope.	'Rend. R. Accad. d. Lincei' [5], ix. I. 196-201.

List of the Chief Abbreviations used in the above Catalogue.

Abbreviated Title.	Full Title.
Amer. J. Sci. . . .	American Journal of Science (Silliman's).
Ann. Agron. . . .	Annales Agronomiques.
Ann. Chem. u. Pharm. .	Annalen der Chemie und Pharmacie (Liebig).
Ann. Chim. et Phys. . .	Annales de Chimie et de Physique.
Ann. de Chim. . . .	Annales de Chimie.
Ann. Obs. Bruxelles . .	Annuaire de l'Observatoire de Bruxelles.
Ann. Phys. u. Chem. [N.F.]	Annalen der Physik und Chemie [Neue Folge] (Wiedemann).
Arch. de Genève . .	Archives des Sciences Physiques et Naturelles (Genève).
Arch. f. Anat. u. Physiol.	Archiv für pathologische Anatomie und Physiologie und für klinische Medicin (Virchow).
Arch. f. d. gesammte Physiol.	Archiv für die gesammte Physiologie (Pflüger).

Abbreviated Title.	Full Title.
Arch. f. exper. Pathol. u. Pharmakol.	Archiv für experimentelle Pathologie und Pharmakologie.
Arch. néerland . . .	Archives néerlandaises des Sciences exactes et naturelles (Haarlem).
Astr. Nachr. . . .	Astronomische Nachrichten.
Astrophys. J. . . .	The Astrophysical Journal (Chicago).
Atti d. R. Accad. d. Lincei	Atti della Reale Accademia dei Lincei.
Beiblätter	Beiblätter zu den Annalen der Physik und Chemie (Wiedemann).
Ber.	Berichte der deutschen chemischen Geselischaft.
Bied. Centr. . . .	Biedermann's Centralblatt für Agriculturchemie.
Bot. Zeitung . . .	Botanische Zeitung.
Bull. Astron. . . .	Bulletin Astronomique (Observatoire de Paris).
Bull. Soc. Chim. . .	Bulletin de la Société Chimique de Paris.
Bull. Soc. Min. de France	Bulletin de la Société Minéralogique de France.
Bull. Acad. Belg. . .	Bulletin de l'Académie royale des Sciences, des Lettres et des Beaux-Arts de Belgique.
Chem. Centr. . . .	Chemisches Centralblatt.
C. R.	Comptes Rendus de l'Académie des Sciences (Paris).
Denkschr. Akad. Wien. .	Denkschriften der Akademie der Wissenschaften in Wien (Mathematisch-naturwissenschaftliche Classe).
Dingl. J.	Dingler's polytechnisches Journal.
Gazz. chim. ital. . .	Gazzetta chimica italiana.
Gött. Nachr. . . .	Nachrichten von der Georg-August-Universität und der königl. Gesellschaft der Wissenschaften (Göttingen).
Handl. Svensk. Vet. Akad.	Handlingar K. Svenska Vetenskaps Akademiens (Stockholm).
Jahrb. f. Photogr. . .	Jahrbuch für Photographie (Eder).
J. Chem. Soc. . . .	Journal of the Chemical Society of London.
J. de Phys. . . .	Journal de Physique.
J. Physiol.	Journal of Physiology.
J. prakt. Chem. . . .	Journal für praktische Chemie.
J. Russ. Phys.-Chem. Soc.	Journal of the Russian Physico-Chemical Society (in Russian).
J. Soc. Chem. Ind. . .	Journal of the Society of Chemical Industry.
J. Soc. franç. de Phys. .	Journal de la Société française de Physique.
Math. u. naturwiss. Ber. aus Ungarn.	Mathematische und naturwissenschaftliche Berichte aus Ungarn.
Mem. spettr. ital. . .	Memorie della Società degli Spettroscopisti italiani.
Monatsb. Akad. Berl. .	Monatsberichte der Akademie der Wissenschaften zu Berlin.
Monatsh. f. Chem. . .	Monatshefte für Chemie (Wien).
Month. Not. R.A.S. . .	Monthly Notices of the Royal Astronomical Society of London.
Oefvers. af K. Vet. Akad. Förh.	Oefversigt af K. Svenska Vetenskaps Akademiens Förhandlingar.
Phil. Mag.	London, Edinburgh, and Dublin Philosophical Magazine.
Phil. Trans. . . .	Philosophical Transactions of the Royal Society of London.
Phot. Mittheil. . . .	Photographische Mittheilungen (Vogel).
Phys. Review . . .	Physical Review.
Phys. Revue . . .	Physikalische Revue.
Proc. Phys. Soc. . . .	Proceedings of the Physical Society of London.
Proc. Roy. Inst. . . .	Proceedings of the Royal Institution of Great Britain.
Proc. Roy. Soc. . . .	Proceedings of the Royal Society of London.
Rec. des trav. chim. des Pays-Bas.	Recueil des travaux chimiques des Pays-Bas.
Rend. R. Accad. d. Lincei	Rendiconti della Reale Accademia dei Lincei.
Rev. gén. des Sci. . .	Revue générale des Sciences pures et appliquées (Paris).
Riv. sci. industr. . .	Rivista scientifico-industriale.

Abbreviated Title.	Full Title.
Sitzungsb. Akad. Berl. . .	Sitzungsberichte der Akademie der Wissenschaften zu Berlin.
Sitzungsb. Akad. München	Sitzungsberichte der königlich baierischen Akademie zu München.
Sitzungsb. Akad. Wien. .	Sitzungsberichte der Akademie der Wissenschaften zu Wien.
Sitzungsb. phys.-med. Soc. Erlangen.	Sitzungsberichte der phys.-medicinischen Societät zu Erlangen.
Skand. Arch. f. Physiol. .	Skandinavisches Archiv für Physiologie (Leipzig).
Verh. phys. Gesellsch. Berlin.	Verhandlungen der physikalischen Gesellschaft zu Berlin.
Versl. d. K. Akad. Wet. Amsterdam.	Verslagen van de Koninklijke Akademie van Wetenschappen te Amsterdam.
Wien. Anz. . . .	Anzeiger der k. Akademie der Wissenschaften zu Wien.
Zeitschr. f. anal. Chem. .	Zeitschrift für analytische Chemie.
Zeitschr. f. anorg. Chem. .	Zeitschrift für anorganische Chemie.
Zeitschr. f. Kryst. u. Min. .	Zeitschrift für Krystallographie und Mineralogie.
Zeitschr. f. physikal. Chem.	Zeitschrift für physikalische Chemie.
Zeitschr. f. phys. u. chem. Unterr.	Zeitschrift für physikalischen und chemischen Unterricht.
Zeitschr. f. physiol. Chem.	Zeitschrift für physiologische Chemie.
Zeitschr. f. wiss. Microscopie.	Zeitschrift für wissenschaftliche Microscopie.

Absorption Spectra and Chemical Constitution of Organic Substances.—Third Interim Report of the Committee, consisting of Professor W. NOEL HARTLEY *(Chairman and Secretary)*, Professor F. R. JAPP, Professor J. J. DOBBIE, and Mr. ALEXANDER LAUDER, *appointed to investigate the Relation between the Absorption Spectra and Chemical Constitution of Organic Substances.*

THE Committee decided to report this year upon the examination of isomeric cyanogen compounds. The preparation of some of these substances in a state of purity had proved to be an exceedingly tedious piece of work, but the labour bestowed has been fully justified by the results obtained.

A further contribution to studies in tautomerism has been completed by an examination of the absorption spectra of dibenzoylmethane and α-oxybenzalacetophenone (α-hydroxybenzylidene acetophenone).

Some work on the subject of dyes and the examination of phloroglucinol and its derivatives has also occupied much attention; this work is, however, not yet quite so complete as to admit of it being embodied in this report. The Committee desire to be reappointed for the purpose of completing the work now in progress.

The Absorption Spectra of Cyanogen Compounds. By WALTER NOEL HARTLEY, *F.R.S.*, JAMES J. DOBBIE, *D.Sc., M.A., and* ALEXANDER LAUDER, *B.Sc.*[1]

The following investigation was undertaken with the view of ascertaining whether by an examination of the absorption spectra of the cyanogen compounds it might be possible to throw some light upon the

[1] *Trans. Chem. Soc.*, 1901, 79, p. 848.

vexed question of the constitution of these substances. Some of the substances of a simple constitution belonging to this group had been previously examined.

W. A. Miller and also L. Soret proved the transparency of hydrocyanic acid and the cyanides,[1] and Hartley, independently, found that hydrocyanic acid is a remarkably diactinic substance which exhibits no trace of selective absorption.[2] Cyanuric acid, owing to difficulties in its examination, arising out of its sparing solubility and the necessity for examining warm solutions, at first appeared to give evidence of selective absorption. It was subsequently proved, however, that there was no absorption band even in layers of liquid 200 mm. thick, but that the rays between wave-lengths 3330 and 2572—that is, to where the spectrum was sharply cut off—were only feebly transmitted.[3]

In the present research some derivatives of cyanic acid have been included, but attention has been directed chiefly to cyanuric acid, melamine, and their respective alkyl derivatives.

The derivatives of cyanic acid which were examined are highly diactinic and show only general absorption.

Cyanuric acid is commonly represented as a closed chain compound in which the chain is formed of alternate atoms of carbon and nitrogen united by alternate double and single bonds (Formula I.), and a similar structure is assigned to the methyl ester (methyl cyanurate; m.p. 135°), which is obtained from cyanuric chloride by the action of sodium methylate. The methyl ester (methyl iso-cyanurate, methyl tricarbimide; m.p. 175°), on the other hand, which is prepared by the distillation of potassium cyanate with potassium methyl sulphate, is represented as a derivative of iso-cyanuric acid (Formula II.), which contains three keto-groups and has the carbon and nitrogen atoms united by single bonds only. In this ester the alkyl radicals are directly united to the nitrogen atoms.

Formula I.	Formula II.
HO.C : N.C.OH | || N : C.N | OH	OC.NH.CO | | HN.CO.NH
Cyanuric acid.	Iso-cyanuric acid or tricarbimide.

Pyridine and dimethylpyrazine, in which there are carbon and nitrogen atoms united by alternate double and single bonds, exhibit strong and persistent absorption bands, the selective absorption being more pronounced in dimethylpyrazine,[4] which contains two nitrogen atoms, than in pyridine, which contains only one. It was therefore to be expected that substances possessing the constitution assigned to normal cyanuric acid and its esters would likewise exhibit marked selective absorption, and that even to a greater extent than dimethylpyrazine.

On the other hand it was to be anticipated that the alkyl derivatives

[1] *Phil. Trans.*, 1862, pp. 861–887; *J. Chem. Soc.*, vol. ii. p. 68; *Arch. des Sciences Phys.*, Geneva, **61**, 1878.
[2] *Trans. Chem. Soc.*, 1882, **41**, p. 45.
[3] *Proc. Chem. Soc.*, 1899, **15**, p. 46.
[4] *Trans. Chem. Soc.*, 1900, **77**, 846.

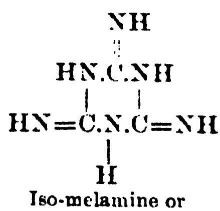
of iso-cyanuric acid (Formula II.) would behave like piperidine and other bodies composed of a closed chain of singly linked carbon atoms or of carbon and nitrogen, where one or more carbons are replaced by nitrogen atoms, and which exhibit general absorption only. All the cyanuric compounds, however, which we have examined show only general absorption, and give no indication of the presence of absorption bands.

This result is what was anticipated in the case of derivatives of iso-cyanuric acid; but so far as cyanuric acid and its esters are concerned it is remarkable—especially when considered in connection with the fact that no strict experimental evidence has yet been advanced in support of the commonly received structural formula for cyanuric acid. Methyl cyanurate (m.p 135°) yields on saponification with alkalies cyanuric acid and methyl alcohol. It is therefore regarded as the ester of normal cyanuric acid (Formula I.), a conclusion which is supported by its method of formation from sodium methylate and cyanuric chloride. Trimethylcarbimide (m.p. 175°), on the other hand, yields methylamine on treatment with alkalies, and is therefore regarded as a derivative of iso-cyanuric acid (Formula II.). It is generally admitted, however, that chemical evidence of this kind and in such cases is frequently unreliable.[1]

In this instance the spectrographic examination confirms the result arrived at on purely chemical grounds. The spectra of methyl cyanurate (m.p. 135°) bear a close resemblance to those of cyanuric acid, the absorption being somewhat greater owing to the replacement of three hydrogen atoms by three methyl groups. On the other hand the spectra of trimethylcarbimide (m.p. 175°), notwithstanding a similar replacement of hydrogen by methyl groups, show considerably less absorption of the more refrangible rays.

Melamine and its esters show only general absorption, the amount being somewhat greater than in the case of cyanuric acid. Melamine is regarded as the triamide of normal cyanuric acid (Formula I.).

Melamine or
cyanurtriamide.



Iso-melamine or
Iso-cyanurtriimide.

The triethyl ester (m.p. 74°), which is obtained by the action of ethylamine on cyanuric chloride, is, from its method of formation, considered to be a derivative of melamine; the ethyl derivative (m.p. 92°), on the other hand, which is prepared by the desulphurisation of thiourea, is regarded as a derivative of iso-melamine. Here again the results of the spectrographic investigation are in accord with the conclusions arrived at on chemical evidence. The spectra of melamine and the triethyl ester (m.p. 74°) are almost identical, while the general absorption exhibited by the spectra of the isomeric ester is considerably less.

The general result of the examination of these bodies is in complete

[1] Goldschmidt and Meissler, *Ber.*, 1890, **23**, 253; A. Michael, *J. pr. Chem.* [ii.], 1885, **37**, 513; Hartley and Dobbie, *Trans. Chem. Soc.*, 1899, **75**, 640.

agreement with the views now generally held as to their relationship with one another. But, as already observed, the absence of selective absorption is not in harmony with the constitution of cyanuric acid when it is represented by a formula so closely analogous to that of pyridine and still more closely to that of dimethylpyrazine. On this account it may fairly be considered as very doubtful whether the constitution of cyanuric acid is rightly understood.

The Absorption Spectra of Dibenzoyl Methane and a-Oxybenzalacetophenone.

These two substances are related to each other in the same manner as Knorr's dibenzoyl succinicesters examined by Hartley and Dobbie.[1] Their constitution is represented by the following formulæ :—

$$\begin{array}{ccc} C_6H_5.CO & \qquad\qquad & C_6H_5.CO \\ | & & | \\ CH_2 & & CH \\ | & & \| \\ C_6H_5.CO & & C_6H_5.COH \end{array}$$

Dibenzoylmethane m.p. 77–78°
α-Oxybenzalacetophenone m.p. 77–78° (α-Hydroxybenzylidene acetophenone)

The enolic form is, in this case, the more stable of the two, the keto form in solution passing rapidly into the enolic form on the addition of an acid. It is the reverse with the dibenzoylsuccinic esters ; the enolic ester passes into the keto form spontaneously.

As the study of cases of this kind is of particular interest, and but few have been examined, Miss Alice E. Smith, B.Sc., of the University College of North Wales, Bangor, kindly undertook, at the request of the committee, to investigate the absorption spectra of these substances. Mr. R. D. Abell, B.Sc., 1851 Exhibition Scholar of the University College of North Wales, Bangor, was good enough to supply pure specimens of these substances for examination.

Dibenzoylmethane ($C_6H_5.CO.CH_2.CO.C_6H_5$). — The preparation of dibenzoylmethane may be divided into the following stages :—

(1) The preparation of benzalacetophenone from benzaldehyde and acetophenone.[2]

(2) Preparation of dibrombenzalacetophenone from benzalacetophenone.[3]

(3) Preparation of monobrombenzalacetophenone from dibrombenzalacetophenone.[4]

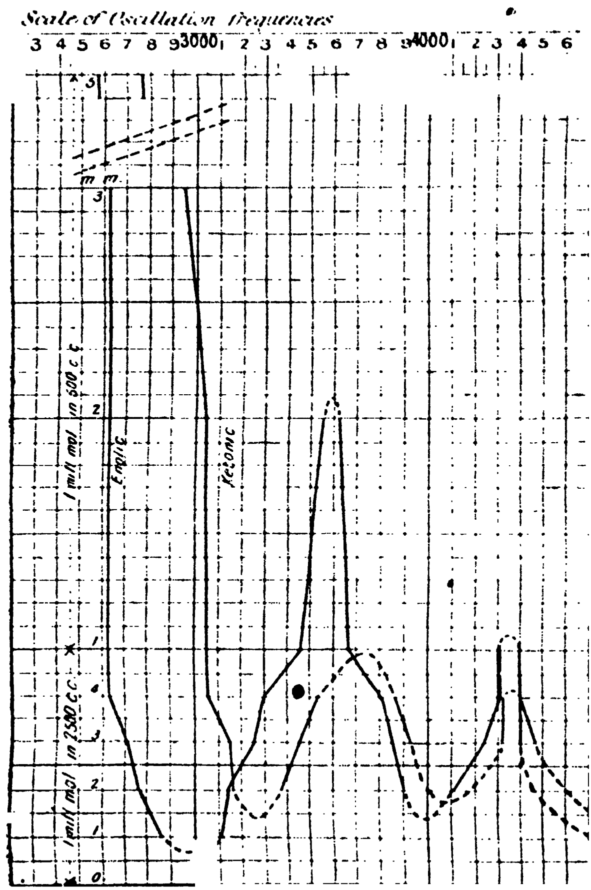
(4) Preparation of dibenzoylmethane from monobrombenzalacetophenone.

a-oxybenzalacetophenone ($C_6H_5.CO.CH:C(OH).C_6H_5$) (or *a*-Hydroxybenzylidene acetophenone).—This substance was prepared by Baeyer and Perkin by heating dibenzoylacetic ester with water.[5] The method of acting with sodium ethoxide or metallic sodium on a mixture of ethyl benzoate and acetophenone employed in the present case has been described by Claisen.[6]

[1] *Trans. Chem. Soc.*, 1900, **77**, 498.
[2] *Ber.*, **20**, 665 ; **14**, 2464 ; **29**, 1492.
[3] *Ann.*, **308**, 323.
[4] *Ann.*, **308**, 226.
[5] *Ber.*, **16**, 2134 ; *Chem. Soc. Trans.*, **47**, 250.
[6] *Ber.*, **20**, 655 ; *Ann.*, **291**, 52.

The method employed in photographing the spectra has already been described.[1]

It will be seen from the accompanying curves that the relation existing between the two bodies is similar to that which exists between Knorr's α- and β-dibenzoylsuccinic esters. Both the substances show



Curves of Molecular Vibrations.—Dibenzoylmethane, Ketonic, α-Oxybenzalacetophenone (α-Hydroxybenzylidene acetophenone), Enolic.

well marked absorption bands, and the amount of general absorption caused by the enolic form is, as in the case of Knorr's esters, considerably greater than that caused by the keto form. In this case the gradual change of the less stable into the more stable form has been traced by photographing the acidified solution at intervals.

[1] *Trans. Chem. Soc.*, 1885, 47, 685.

Dibenzoyl Methane

The Ketonic Form

$$\begin{array}{c} C_6H_5.CO \\ | \\ CH_2 \\ | \\ C_6H_5.CO \end{array}$$

Thickness of Layer of Liquid in Millimetres	Description of Spectrum	$\frac{1}{\lambda}$	λ
	1 Milligramme Mol. in 100 c.c. Alcohol.		
5	Spectrum continuous to . .	2624	3810
	Complete absorption beyond.		
4	Spectrum continuous to . .	2624	3810
	Complete absorption beyond.		
3	Spectrum continuous to . .	2701	3702
	Complete absorption beyond.		
2	Spectrum continuous to . .	2760	3623
	Complete absorption beyond.		
	1 Milligramme Mol. in 500 c.c. Alcohol.		
5	Spectrum continuous to . .	2786	3589
	Complete absorption beyond.		
4	Spectrum continuous to . .	2871	3483
	Complete absorption beyond.		
3	Spectrum continuous to . .	2965	3372
	Complete absorption beyond.		
2	Spectrum continuous to . .	3057	3271
	Complete absorption beyond.		
	1 Milligramme Mol. in 2.500 c.c. Alcohol.		
5	Spectrum continuous to . .	3057	3271
	Complete absorption beyond.		
4	Spectrum continuous to . .	3057	3271
	Absorption band	*3057* to *3555*	*3271* to *2812*
	Strong rays transmitted from 3555 to	3873	2581
	Absorption band	*3873* to *4306*	*2581* to *2322*
	Weak spectrum from 4306 to .	4400	2272
	Complete absorption beyond.		
3	Spectrum continuous to . .	3141	3183
	Absorption band	*3141* to *3465*	*3153* to *2886*
	Spectrum continuous to . .	3911	2556
	Absorption band	*3911* to *4306*	*2556* to *2322*
	Spectrum continuous from 4306 to	4400	2272
	Complete absorption beyond.		
2	Spectrum continuous to . .	3175	3149
	Strong rays partially transmitted from 3175 to	3381	2957
	Spectrum continuous from 3381 to	3911	2556
	Strong rays partially transmitted from 3911 to	4306	2322
	Spectrum continuous from 4306 to	4400	2272
	Weak spectrum from 4400.		
	Spectrum continuous . . .	—	—

a-Oxybenzalacetophenone $C_6H_5.CO$
(a-Hydroxybenzylidene acetophenone) CH
The Enolic Form $C_6H_5.C(OH)$

Thickness of Layer of Liquid in Millimetres	Description of Spectrum	$\frac{1}{\lambda}$	λ
	1 *Milligramme Mol. in* 100 *c.c. Alcohol.*		
5	Spectrum continuous to . .	2545	3929
	Complete absorption beyond.		
4	Same as 5 mm.	—	—
3	Spectrum continuous to . .	2552	3918
	Complete absorption beyond.		
2	Same as 3 mm.		—
	1 *Milligramme Mol. in* 500 *c.c. Alcohol.*		
5	Spectrum continuous to . .	2591	3859
	Complete absorption beyond.		
4	Same as 5 mm.		—
3	Spectrum continuous to . .	2624	3810
	Complete absorption beyond.		
2	Spectrum continuous to . .	2624	3810
	Complete absorption beyond, except for the feeble transmission of strong lines at .	3535	2812
	And at.	3625	2758
	1 *Milligramme Mol. in* 2,500 *c.c. Alcohol.*		
5	Spectrum continuous to . .	2624	3810
	Absorption band	*2624* to *3461*	*3810* to *2889*
	Strong rays partially transmitted from 3461 to	3677	2719
	Absorption band	*3677* to *4306*	*2719* to *2322*
	Weak spectrum from 4306 to .	4400	2272
	Complete absorption beyond.		
4	Spectrum continuous to . .	2624	3810
	Absorption band	*2624* to *3280*	*3810* to *3048*
	Spectrum continuous from 3280 to	3805	2628
	Absorption band	*3805* to *4306*	*2628* to *2322*
	Spectrum continuous from 4306 to	4400	2272
	Complete absorption beyond.		
3	Spectrum continuous to . .	2701	3702
	Absorption band	*2701* to *3260*	*3702* to *3067*
	Spectrum continuous from 3260 to	3866	2586
	Absorption band	*3866* to *4258*	*2586* to *2348*
	Spectrum continuous from 4258 to	4400	2272
	Complete absorption beyond, except for the feeble transmission of lines at . . .	4539	2203
	And	4645	2153
2	Spectrum continuous to . .	2760	3623
	Absorption band	*2760* to *3139*	*3623* to *3185*
	Spectrum continuous from 3139 to	3905	2560

a-Oxybenzalacetophenone (The Enolic Form)—cont.

Thickness of Layer of Liquid in Millimetres	Description of Spectrum	$\frac{1}{\lambda}$	λ
1	*Absorption band*	*3905 to 4100*	*2560 to 2439*
	Spectrum continuous from 4100 to	4100	2272
	Strong rays feebly transmitted beyond.		
	Spectrum continuous to . .	2871	3483
	Strong lines transmitted from 2871 to	3130	3194
	Spectrum continuous from 3130 to	3905	2560
	Strong lines transmitted from 3905 to	4100	2439
	Spectrum continuous beyond. Transmission of a continuous spectrum on further dilution of the solution.		

The Absorption Spectra of Indophenols and Dyes derived from Triphenylmethane.

As much work has recently been published on the relationship between the constitution of dyes and their absorption spectra, abstracts of the more important of these memoirs are given, accompanied by remarks on the conclusions drawn from previous examinations of triphenylmethane derivatives.

Relation entre la constitution chimique des colorants du triphénylméthane et les spectres d'absorption de leurs solutions aqueuses. Note de M. P. Lemoult.[1]

The examination of the absorption spectra of a large number of artificial colouring matters was made in the hope of finding some characteristic belonging to each of the principal groups which enter into their constitution, but up to the present the study of such colours as are derived from triphenylmethane has led to nothing more than a demonstration of some connection between the position of the luminous bands of these spectra and the constitution of the products examined. All the solutions were so made that a gramme-molecule of the dye was contained in 1,000 litres of water, the thickness of liquid being variable. The following were the substances investigated :—

1. Malachite green.
2. Brilliant green.
3. Sulpho-green J.
4. Sulpho-green B.
5. Green *o*-nitro.
6. Green *m*-nitro.
7. Solid green with alkali.
8. Carmine blue.
9. Victoria blue.
10. Phenyl blue, or phenylated blue.
11. Methyl green.
12. Hexamethylated violet.
13. Hexethylated violet.
14. Formyl violet.
15. Acid violet 10 B.
16. Benzyldiphenylamine violet.
17. Benzylated violet.

[1] *Comptes Rendus*, vol. cxxxi. 1900, p. 839

The nature of the substitutions in the three benzene nuclei is explained by the author. Observed in thickness of 6 mm. some of the substances show simply a band of transmitted rays in the red, others are also in the violet of much larger extent. The red band is much more persistent, and apparently is characteristic of the triphenylmethane group of substances and not of the individual members of this group. The band in the red belonging to the greens and blues, Nos. 1 to 11, is narrower than in the remaining colours, which are violet—namely, Nos. 12 to 17.

NOTE.—The formulæ given by Nietzki for some of the dye-stuffs examined are the following :—

1. *Malachite green.*

$$\begin{array}{l} C_6H_5C=[C_6H_4N(CH_3)_2]_2 \\ \quad | \\ \;\; OH \end{array}$$

2. *Brilliant green.*

$$\begin{array}{l} C_6H_5C=[C_6H_4N(C_2H_5)_2]_2 \\ \quad | \\ \;\; OH \end{array}$$

9. *Victoria blue B.*

$$\begin{array}{l} (CH_3)_2N-C_6H_4 \diagdown \qquad \diagup C_{10}H_6-NHC_6H_5 \\ \qquad\qquad\qquad\quad C \qquad\qquad\qquad\quad | \diagdown \\ (CH_3)_2N-C_6H_4 \diagup \qquad \diagdown \qquad\qquad\qquad\quad Cl \end{array}$$

11. *Methyl green.*

$$\begin{array}{l} \qquad\qquad\qquad\qquad\quad \diagup C_6H_4N(CH_3)_2CH_3Cl \\ (CH_3)_2N-C_6H_4-C \\ \qquad\qquad\qquad\qquad\quad \diagdown C_6H_4N(CH_3) \\ \qquad\qquad\qquad\qquad\qquad\qquad\quad | \diagdown Cl \end{array}$$

12. *Hexamethylated violet.*

$$\begin{array}{l} \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad \diagup Cl \\ [(CH_3)_2N.C_6H_4]_2=C-C_6H_4N(CH_3)_2 \end{array}$$

13. *Hexethylated violet.*

A similar formula with C_2H_5 substituted for CH_3.

The author's summary is as follows :—The colours derived from triphenylmethane, which have in general at least two atoms of tertiary nitrogen in the *para*-position relative to the central carbon atom, yield aqueous solutions in which the absorption spectrum transmits a band of rays in the red. The middle of this band is always situated at approximately the wave-length 686 in those compounds which have no more than two tertiary nitrogen groups. The position is invariable, but different for those which include a third tertiary nitrogen group, and lies about wave-length 666.

Sur l'absorption de la lumière par les indophénols *By* P. BAYRAC *and* C. CAMICHEL.[1]

The indophenols with tertiary nitrogen, prepared by one of the authors, were studied, and it was found that when dissolved in the same solvent, as. for instance, alcohol, they presented an analogous spectrum in every case. They are characterised by a band in the red. Lemoult studied a series of indophenols obtained by the oxidation of mixtures of *p*-phenylenediamine and phenol or *o*-cresol, which have in the *para*-position the nitrogen atom which unites the two benzene nuclei. The nitrogen in this case is primary and not tertiary. The substances are said to have a band in the red which is shifted from the position characteristic of indophenols containing tertiary nitrogen. The authors state that there may be displacement of the band, but it has no definite direction; and the experiments of Lemoult do not show that it has. The method of measuring adopted by Lemoult is to take the mean of the micrometer readings between either edge of the band. It is remarked that the extreme reading at the extremity of least refrangible rays is not the end of the band, but merely the limit of visible rays, and that this is variable according to the brilliancy of the spectrum. They give reasons for this statement which are capable of verification, and also for the explanation that there *appears* to be a displacement, but the band really terminates in the infra-red.

Sur les spectres d'absorption des indophénols et des colorants du triphénylméthane. *By* C. CAMICHEL *and* P. BAYRAC.[2]

The indophenols with the tertiary nitrogen are much more absorbent than those with the primary nitrogen when the two are compared in solutions containing molecular proportions; but the fact is that as the less refrangible end of the band visible in the red lies in the infra-red there can be no increased width visible in this direction, and the rays on the other side being more freely transmitted, it appears as if the band had been shifted towards the more refrangible rays. This having been demonstrated with the two kinds of indophenols, it was thought desirable to study the triphenylmethane derivatives—malachite green, sulpho-green J, hexamethylene violet crystals, and methyl green. The result was just the same; only one extremity of the band of red rays lies within the region of visibility. The conclusion is that the law of auxochromes has not been demonstrated in the case of triphenylmethane derivatives nor of indophenols. The number of tertiary nitrogens in the molecule is the factor which increases the absorbent power of the substance, just as the substitution of $(CH_3)_3$ for H_3 in indophenols, or *vice versâ*, renders the substance more or less powerfully absorbent. The authors state that they have studied the influence of concentration upon alcoholic solutions of indophenols and on aqueous solutions of those colouring matters derived from triphenylmethane. They have found that the coefficient of absorption is proportional to the concentration of the solution.

NOTE.—The nature of the indophenols is indicated by the following formulæ and reactions, the notes being taken from Bernthsen's 'Organic Chemistry' and Witt's original papers.[3]

[1] *Comptes Rendus*, vol. cxxxii. 1901, p. 338. [2] *Ibid.*, cxxxii. 1901, p. 485.
[3] Berichte, 16, 2843, and 18, 2912.

Indophenols. *By* OTTO WITT.

Phenol blue (indo-aniline)—

$$N\begin{cases} C_6H_4.N(CH_3)_2 \\ C_6H_4.O \end{cases}$$

is produced by the oxidation of amidodimethylaniline with phenol.

Its analogue, α-naphthol blue,

$$N\begin{cases} C_6H_4.N(CH_3)_2 \\ C_{10}H_{16}O \end{cases}$$

is prepared by means of naphthol. Such compounds exchange $N(CH_3)_2$ for OH when boiled with a solution of NaOH ; thus, from phenol blue there results indophenol (quinonephenolimide)

$$N\begin{cases} C_6H_4.OH \\ C_6H_4O \end{cases}$$

a phenolic dye which dissolves in alcohol to a red and in alkali to a blue solution.

It may be obtained also by the action of phenol upon quinone chlorimide.

$$C_6H_4\begin{cases} O \\ | \\ NCl \end{cases} + C_6H_5OH = C_6H_4\begin{cases} O \\ | \\ N-C_6H_4OH \end{cases}$$

$$= N\begin{cases} C_6H_4.OH \\ C_6H_4.O \end{cases} + HCl$$

It may be obtained also by the oxidation of p-amidophenol with phenol. Its leuco-compound is p-dihydroxydiphenylamine, $NH(C_6H_4.OH)_2$, a substance which unites in itself the properties of diphenylamine and a diatomic phenol.

Sur la loi des auxochromes. *By* M. P. LEMOULT.[1]

In a recent note MM. Camichel and Bayrac having expressed the opinion that the law of auxochromes has no further application to the compounds of triphenylmethane than to the indophenols, the author believes that this statement is not sufficiently justified, having regard to his observations on four different colouring matters, namely :—

First group (with 2 tertiary nitrogens)	No. 1. Oxalate of tetramethyldiamidotriphenyl carbinol. No. 2. Sulphate of tetrethyldiamidotriphenyl carbinol.
Second group (with 3 tertiary nitrogens)	No. 3. Chlorhydrate of hexethyltriamidotriphenyl carbinol. No. 4. Dimethyldiethyldibenzyltriamidotriphenyl carbinol sodium disulphonate.

[1] *Comptes Rendus*, cxxxii. p. 784, March 25, 1901.

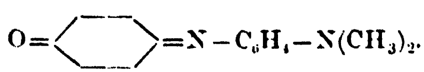
Solutions were made of such a strength that 1 gramme-molecule was contained in 1,000 litres of water. Photographs of the transmitted rays were taken through a constant thickness with a constant exposure and exactly the same development. The photographs reproduced in the paper are explained in the text. They exhibit a luminous band in the red which in respect to substances 1 and 2 is the same in intensity and position. In substances 3 and 4 it is more luminous and slightly broader, and the luminous band of No. 3 lies rather more towards the less refrangible rays than No. 4. Wave-length measurements are not given, but numbers on an arbitrary scale are recorded. On diluting these solutions, the change in the spectrum is seen to be a decrease of the intensity of the absorption bands more on the side of the rays of greater refrangibility than on the other. The author proposes to enunciate definitely the law of auxochromes in a future paper.

NOTE.—That there is apparently a decrease in the intensity of the absorption bands more in the direction of the rays of shorter wave-length is due undoubtedly in the first instance to the property of the prism, there being greater dispersion of the more refrangible rays.

Nouvelle méthode permettant de charactériser les matières colorantes.
By MM. CAMICHEL *and* BAYRAC.[1]

The absorption of light by solutions of indophenols in alcohol, ether carbon disulphide, and chloroform has been studied by taking as abscissæ the wave-lengths and as ordinates the coefficients of transmission. Curves have been obtained of parabolic form, of which the convexity is turned from the side of the axis of the abscissæ. That portion of the curve corresponding to the transmitted red rays ascends much more rapidly than that which corresponds to the green or the blue. The minimum position of the ordinate lies between the wave-lengths 610 and 535 according to the nature of the indophenol and its solvent. In order to characterise each of the substances studied, the lowest point of the curve was determined—that is to say, its minimum of transmission or of greatest absorption. This is determined with precision by cutting the curve with a series of lines or chords lying parallel to the axis of the abscissæ. The conjugate diameter of these chords, obtained by joining points at the middle of each line, is rectilinear in a sufficiently large interval lying between wave-lengths 670 and 510: in such a case, for example, as that of an alcoholic solution of indophenol and of orthocresol with two tertiary nitrogens. The minimum of transparency (maximum of absorption) is independent of the concentration of the solution for all substances of which the absorption coefficient is proportional to the degree of concentration, according to the law of Beer. It varies with the solvent according to a law which is not that indicated by Kundt.

Two series of indophenols have been studied; those of Series A have two tertiary nitrogens, the simplest of which is indophenol of ordinary phenol.



The others (Series B) have the second tertiary nitrogen replaced by

[1] *Comptes Rendus*, cxxxii. p. 882, April 9, 1901.

a primary nitrogen, the simplest of which is the indophenol of ordinary phenol.

Table of the indophenols studied.

Series A.		Series B.	
1.	Indophenol of phenol.	1′.	Indophenol of phenol.
2.	,, orthocresol.	2′.	,, orthocresol.
3.	,, metacresol.	3′.	,, metacresol.
4.	,, paraxylenol.	4′.	,, paraxylenol.
5.	,, orthoethylphenol.	5′.	,, orthoethylphenol.
6.	,, metaisopropylphenol.	6′.	,, metaethylphenol.
7.	,, thymol.	7′.	,, thymol.
8.	,, carvacrol.	8′.	,, carvacrol.
9.	,, cymophenol.	9′.	,, cymophenol *a*.
10.	,, phenol *a* of the para-ethyltoluene.	10′.	,, phenol *a* of the para-ethyltoluene.
		11′.	,, orthoxylenol (1, 2, 3).
		12′.	,, metaxylenol (1, 2, 3).

a. The displacement of the minimum of transparency (maximum of absorption) under the effect of a solvent is shown by the following numbers representing divisions of the micrometer eyepiece. The substance was No. 1.

Alcohol.	Ether.	Carbon disulphide.	Chloroform.
120	169	147	128

The rays observed with the spectrophotometer gave the following measurements :—

Solar A.	7·0	Ca 1st	104	Tl	220
B.	49·5	Ca 2nd	104	Solar E	235
Li	60·5	Solar D 1	138		
Solar C.	72·5	D 2	139		

b. When the tertiary nitrogen had been replaced by a primary nitrogen the following numbers were obtained :—

Solvent, alcohol.

1. 120	1′. 142	displacement	+ 22
2. 136	2′. 162		+ 26
3. 122	3′. 142		+ 20

c. By the introduction of the following alkyl radicals into the *ortho*-position, the displacements shown below were measured :—

$$CH_3,\ C_2H_5,\ CH{<}^{CH_3}_{CH_3},\ CH_2-CH_2-CH_3.$$

Solvent, alcohol.

1. 120	2. 136	displacement	+ 16	Substitution of CH_3
3. 122	4. 134		+ 12	CH_3
7. 117	9. 136		+ 19	CH_2

A similar series of experiments was made on substitution in the *meta*-position, the results being as follows :—

1. 120	3. 122	displacement + 2	substitution of CH_3
2. 136	4. 134	− 2	CH_3

Conclusions.—a. When a tertiary nitrogen is replaced by a primary nitrogen, the minimum of transparency (maximum of absorption) is displaced towards the more refrangible end of the spectrum, whatever the solvent may be—alcohol, ether, carbon disulphide, or chloroform.

It is remarked that this law differs entirely from that indicated by M. Lemoult, who studied the apparent displacement of the band of red rays transmitted by indophenols.

b. Substitution in the *ortho*-position in the phenol from which the indophenol is derived causes a considerable displacement of the minimum of transparency (maximum of absorption), whatever the solvent may be. This displacement may even exceed the foregoing in degree. The importance of substitution is thus evident ; the auxochromic groups are not the only ones to modify the nature of the dye.

c. A substitution in the *meta*-position in the phenol from which the indophenol is derived causes a *very slight* displacement of the minimum of transparency towards the red or towards the blue ; the shifting is often so slight as not to exceed experimental errors in measurement.

The preceding two laws, the authors remark, enable the formula of a phenol to be determined ; it is converted into the indophenol with a primary or a tertiary nitrogen, and the alcoholic solution is then examined. Only an extremely small quantity of the substance is required.

NOTE.—Hartley has shown [1] the relationship of the absorption spectra of benzene and triphenylmethane to the colouring matters derived therefrom by means of curves of molecular vibrations.

No matter what their colour may be, a band of red rays is transmitted with greater persistency than the rays in any other part of the spectrum, and that these red rays are materially modified by the introduction of alkyl radicals into the NH_2 groups of the rosaniline molecule, as in methyl-violet, and they are more modified by the presence of iodine, as in iodine green.

To illustrate this the following measurements of the transmitted red rays in solutions at different dilutions and of different thicknesses are stated both in wave-lengths and oscillation frequencies. The fiducial lines in the solar spectrum are also given as useful for reference.

	$\frac{1}{\lambda}$	λ		$\frac{1}{\lambda}$	λ
A	1314	7604	E	1897	5269
B	1455	6867	F	2056	4860
C	1523	6562	G	2321	4307
D	1696	5892	H	2519	3967

[1] *Chem. Soc. Trans.*, vol. li. 1887, p. 152 ; see also the report of this Committee, 1899, p. 31.

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Rosaniline Base.

Thickness	Rays transmitted $\frac{1}{\lambda}$	Rays transmitted λ	Mean
	0·301 *gr. or* 1 *Milligramme-molecule in* 100 *c.c. of Alcohol.*		
MM.			
20	139 to 153	719 to 650	684·5
4	to 166	to 600	---
1	to 166	to 600	—
	1 *Milligramme-molecule in* 500 *c.c.*		
4	to 166	to 600	659·5
	1 *Milligramme molecule in* 12,500 *c.c.*		
4	139 to 137	719 to 562	640·5

Rosaniline Hydrochloride.

Thickness	Rays transmitted $\frac{1}{\lambda}$	Rays transmitted λ	Mean
	0·3375 *gr. or* 1 *Milligramme-molecule in* 100 *c.c. of Water.*		
MM.			
20	139 to 149	719 to 669	694
5	to 157	to 636	677·3
	1 *Milligramme-molecule in* 500 *c.c.*		
4	to 166	to 600	659·5
3	to 166	to 600	659·5
	1 *Milligramme-molecule in* 12,500 *c.c.*		
4	to 174	to 572	
3	to 177	to 562	---
2	139 to 177	719 to 562	619·5

Methyl Violet.

Thickness	Rays transmitted $\frac{1}{\lambda}$	Rays transmitted λ	Mean
	0 416 *gr. or* 1 *Milligramme-molecule in* 100 *c.c. of Alcohol.*		
MM.			
25	139	719	—
20	139 to 145	719 to 686	702·5
5	to 149	to 670	694·5
1	139 to 153	719 to 650	679 5
	1 *Milligramme-molecule in* 500 *c.c.*		
5	139 to 153	719 to 650	—
4	to 156	to 639	—
2	to 158	to 632	—
1	139 to 160	719 to 624	659·5
	1 *Milligramme-molecule in* 12,500 *of Alcohol.*		
5	139 to 166	719 to 600	—
4	to 166	to 600	—
3	139 to 168	719 to 598	658·5

Iodine Green.

Thickness	Rays transmitted $\frac{1}{\lambda}$	Rays transmitted λ	Mean
	0·672 *gr. or* 1 *Milligramme-molecule in* 100 *c.c. of Water.*		
MM.			
20	—	—	—
10	—	—	—
5	133 to 139	749 to 719	—
4	to 139	to 719	—
2	133 to 139	749 to 719	—
	1 *Milligramme-molecule in* 500 *c.c.*		
5	133 to 144	749 to 694	721·5
4	to 147	to 680	—
3	to 148	to 675	—
2	to 149	to 669	—
1	133 to 151	749 to 660	704·5
	1 *Milligramme-molecule in* 2,500 *c.c.*		
5	133 to 151	749 to 660	—
4	133 to 151	749 to 650	699·5
3	—	—	—

Aurine.

Thickness	Rays transmitted $\frac{1}{\lambda}$	Rays transmitted λ	Mean
	0·29 gr. or 1 Milligramme-molecule in 100 c.c. of Water.		
MM.			
60	139 to 153	719 to 650	—
30	to 166	to 600	—
15	to 166	to 600	—
10	to 166	to 600	659·5
5	to 177	to 562	—
4	to 177	to 562	—
3	to 181	to 550	—
2	to 183	to 545	-
1	139 to 188	719 to 530	624·5
	1 Milligramme-molecule in 500 c.c.		
5	139 to 188	719 to 530	—
4	to 192	to 520	—
3	to 193	to 516	—
2	to 195	to 511	—
1	139 to 198	719 to 504	611·5
	1 Milligramme-molecule in 2,500 c.c.		
5	139 to 198	719 to 504	—
4	to 202	to 494	-
3	139 to 206	719 to 484	601·5

It may here be remarked that in the diagram given in the 'Trans. Chem. Soc.' vol. li. 1887, pp. 152–202, of benzene and its derivatives (1) the relationship of the absorption curves to the chemical constitution of these substances is fully described; (2) the band in the red is indicated on the less refrangible side as not being the termination of the transmitted rays, but as the 'extreme limit of the visible spectrum,' and on p. 201 it is pointed out that 'instances where the light is almost entirely absorbed are indicated by the curve being continued by a dotted line, as in rosaniline hydrochloride,' and also that 'iodine green appeared to transmit more of the least refrangible red rays than the other rosaniline derivatives. This may have been due to the colour being favourable to viewing this end of the spectrum, the more brilliant rays being absorbed, and those that are feeble thus rendered visible.' This observation has been verified by MM. Bayrac and Camichel's examination of other substances of a similar character.

It should, however, be distinctly understood that it is the absorption bands which are of prime importance in the study of spectra.

It is the position and width of these which determine those of the transmittent rays, and therefore greater attention should be paid to measurements of the bands of absorption. Comparisons of spectra measured on an arbitrary scale are liable to be very misleading when deductions are drawn from them.

The apparent shifting of the band of transmitted rays in the red observed by Lemoult is satisfactorily shown by Bayrac and Camichel to be only apparent, and not a real alteration in position.

The remark of Bayrac and Camichel that indophenols with tertiary nitrogen groups are much more absorbent than those with primary nitrogen is only what might be predicted from what we know of the ultra-violet spectra. The homologues of benzene, such as toluene, ethylbenzene, and the xylenes, are more powerfully absorbent than benzene itself. The tertiary monamines trimethylamine and triethylamine are more absorbent than the corresponding primary bases. Moreover, it was proved in the case of dyes that in the triphenylmethane derivatives the replacement of 3H by $(CH_3)_3$ rendered the substance much more powerfully absorbent, methyl violet and rosaniline hydrochloride being a case in point. This is best shown by the curves which illustrate the original paper; but it also appears from the measurements which have already been quoted, if we consider that the red rays are freely transmitted by the rosanile salt when even stronger solutions than those containing a milligramme-molecule of substance in 100 c.c. The methyl derivative barely transmits any light through 25 mm. of such a solution. Then, again, the width of the band transmitted by the methyl violet is narrower. The same observation applies to iodine green.

The mere position of a band of transmitted red rays cannot be considered as indicative of a constitution similar to that of the triphenyl methane derivatives or of the indophenols because many of the diazo-colours show such a band. The difference between them lies in the effect of dilution; in fact it is the absorption curves which are of importance, or, better still, the curves of molecular vibrations. There is a particular curve for each class of derivatives, the particular members of each class showing variations of the curve characteristic of the class. This is more marked in the case of the azobenzene and azonaphthalene derivatives than it is even in the derivatives of triphenylmethane, because a larger number of individual substances belonging to the former class have been examined than of the latter. It is quite evident that the nitrogen groups are chiefly concerned in the development of the colours, and the hydrocarbon radicals appear to be of comparatively small importance provided they are of a benzenoid character.

APPENDIX.

List of Substances the Absorption Spectra of which have been studied connection with the Chemical Constitution of Organic Compounds.

NOTE.—The method of indexing adopted by the Chemical Society has been followed.

Substance	Formula	Nature of Absorption	Reference
	A		
cetic Acid .	CH_3COOH	Continuous	Hartley and Huntin ton, *Phil. Trans.* (1879), 257; Schön *Wied. Ann.* 6 (Ne Series), 1879, 267.
cetic Acid—Barium salt of	$(CH_3.COO)_2Ba$	„	Hartley and Huntin ton, *Phil. Trans.* (1879), 259.
cetic Acid—Sodium salt of	CH_3COONa	„	„

Substance	Formula	Nature of Absorption	Reference
Acetaldoxime	$CH_3.CH:N.OH$	Continuous	Hartley and Dobbie, *Chem. Soc. Trans.* 77 (1900), 318.
Acetoxime	$(CH_3)_2C:N.OH$	"	"
Acetylene	C_2H_2	"	Hartley, *Chem. Soc. Trans.* 39 (1881), 158.
Acid Brown—Sodium salt of	$\overset{a}{H}SO_3.C_{10}H_6.\underset{a}{N}:\underset{a}{N}.C_{10}H_6OH$	One band	Hartley, *Chem. Soc. Trans.* 51 (1887), 158.
Aconitine (from Aconitum napellus)	$C_{33}H_{49}NO_{12}$	Selective	Hartley, *Phil. Trans.* II. (1885), 471.
Aconitine (Japaconitine)	$C_{66}H_{88}.N_2O_{21}$	"	"
Aconitine (pseud-) (from Aconitum ferox)	$C_{36}H_{43}NO_{12}$	"	"
Aconitine (foreign)	?	Continuous	"
Alanine	$CH_3.CH(NH_2)COOH$	"	J. L. Soret, *Archives des sciences physiques et naturelles*, 1893 (3rd Series), 429.
Aldehyde Green (A rosaniline derivative)		Selective	Vogel, *Ber.* 11 (1878), 1363.
Alizarin	$C_6H_4(CO)_2C_6H_2(OH)_2$	"	Vogel, *Ber.* 11 (1878), 1363; Liebermann, *Ber.* 19 (1886), 2327; 21 (1887), 2527.
Alizarin ethyl ester	$C_6H_4(CO)_2C_6H_2(OC_2H_5)_2$	"	Liebermann, *Ber.* 21 (1887), 2527.
Allantoïn	$C_4H_6N_4O_3$	Continuous	J. L. Soret, *Archives des sciences physiques et naturelles*, 1893 (3rd Series), 429.
Alloxan	$CO\langle\begin{smallmatrix}NH-CO\\NH-CO\end{smallmatrix}\rangle CO$	"	"
Allylic Alcohol	C_3H_5OH	"	Hartley, *Chem. Soc. Trans.* 39 (1881), 158.
Amido-azo-benzene	See under *Azo Compounds.*		
Amido-azo-a-naphthalene	See under *Azo.*		
Ammonium Hydroxide	$NH_4.OH$	"	Hartley and Huntington, *Phil. Trans.* I. (1879), 257; Hartley and Dobbie, *Chem. Soc. Trans.* 77 (1900), 318; Schönn, *Wied. Ann.* 6 (1879), 267.
Amylene (B.P.)	C_5	"	Hartley, *Chem. Soc. Trans.* 39 (1881), 158
Amylic Acetate	$CH_3COO.C_5H_{10}$	"	Hartley and Huntington, *Phil. Trans.* I. (1879), 257.
Amylic Alcohol	—	—	Schönn, *Wied. Ann.* 6 (New Series) (1879), 267.
Amylic Butyrate	$C_3H_7COOC_5H_{10}$	Continuous	Hartley and Huntington, *Phil. Trans.* I. (1879), 257.
Amylic Formate	$HCOO.C_5H_{10}$	"	"
Amylic Propionate	$C_2H_5.COO.C_5H_{10}$	"	"

APPENDIX—*cont.*

Substance	Formula	Nature of Absorption	Reference
Aniline	$C_6H_5NH_2$	Selective	Hartley and Huntington, *Phil. Trans*, I. (1879), 257; Pauer, *Wied. Ann. der Phys.* 61 (1897), 363.
Aniline Blue	$C_{20}H_{16}(C_6H_5)_3N_3.HCl$	,,	Melde, *Pogg. Ann.* 126 (1865), 264.
Anthracene	$C_{14}H_{10}$	Four bands	Hartley, *Chem. Soc. Trans.* 39 (1881), 153.
Apomorphine Hydrochloride	$C_{17}H_{17}NO_2.HCl$	Selective	Hartley, *Phil. Trans.* II. (1885), 471.
Atropine	$C_{17}H_{23}NO_3$	Continuous	,,
Anthraflavic Acid (2 : 6)—Dioxyanthraquinone	$OH.C_6H_3(CO)_2.C_6H_3.OH$	—	—
Anthraflavic Acid	$C_6H_3OH(CO)_2C_6H_3(OH)$	Selective	Libermann and Kostanecki, *Ber.* 19 (1886), 2327; Liebermann, *Ber.* 21 (1887), 2527.
Iso - Anthraflavic Acid (2 : 7) — Dioxyanthraquinone	$OH.C_6H_3(CO)_2.C_6H_3.OH$	,,	,,
Anthragallol	$C_6H_4\left\langle{CO \atop CO}\right\rangle C_6H(OH_3)$ [1 : 2 : 3]	,,	,,
Aurin	$C_{19}H_{14}O_3$	,,	Hartley, *Chem. Soc. Trans.* 51 (1887), 153.
Anthrarufin	$C_6H_4(CO)_2C_6H_2(OH)_2$ [1.5]	,,	Libermann and Kostanecki, *Ber.* 19 (1886), 2327.
Azo Compounds:			
Amido - azo - benzene	$N_2\begin{cases}C_6H_4NH_2\\C_6H_5\end{cases}$	,,	Landauer, *Ber.* 14 (1881), 391.
Amido - azo - α - naphthalene	$C_{10}H_7N{:}N.C_{10}H_6NH_2$	,,	Hartley, *Chem. Soc. Trans.* 51 (1887), 153; Landauer, *Ber.* 14 (1881), 391.
Azo-benzene	$C_6H_5N{:}NC_6H_5$	,,	Hartley, *Chem. Soc. Trans.* 51 (1887), 153.
Azo-benzene diamido toluene	$N_2\begin{cases}C_6H_5\\C_6H_2.CH_3(NH_2\end{cases}$	,,	Landauer, *Ber.* 14 (1881), 391.
o-Azo-toluene-diamido-benzene	$N_2\begin{cases}C_6H_4.CH_3\\C_6H_3(NH_2)_2\end{cases}$	,,	,,
o-Azo-toluene-diamido-toluene	$N_2\begin{cases}C_6H_4.CH_3\\C_6H_2.CH_3(NH_2)_2\end{cases}$	,,	,,
p-Azo-toluene-diamido-benzene	$N_2\begin{cases}C_6H_4.\overset{p}{C}H_3\\C_6H_3(NH_2)_2\end{cases}$	,,	,,
p-Azo-toluene-diamido-toluene	$N_2\begin{cases}C_6H_4.\overset{p}{C}H_3\\C_6H_2.CH_3(NH_2)_2\end{cases}$	,,	,,
Benzene - azo - β - naphthol sulphonic acid (Sodium Salt)	$C_6H_5N{:}N.C_{10}H_4(HSO_3)_2OH$ β	One band	Hartley, *Chem. Soc Trans.* 51 (1887) 153.
Di - amido - azo - benzene (Chrysoidin)	$N_2\begin{cases}C_6H_3(NH_2)_2\\C_6H_5\end{cases}$	Selective	Hartley, *Chem. Soc Trans.* 51 (1887) 153; Landauer, *Ber* 14 (1881), 391.
Di - amido - azo - benzene sulphonic acid	$N_2\begin{cases}C_6H_3(NH_2)_2\\C_6H_4SO_3H\end{cases}$	,,	Landauer, *Ber.* 14 (1881), 391.

APPENDIX—*cont.*

Substance	Formula	Nature of Absorption	Reference
Di-methyl-amido-azo-benzene	$N_2 \begin{cases} C_6H_4N(CH_3)_2 \\ C_6H_5 \end{cases}$	Selective	Landauer, *Ber.* 14 (1881), 391.
Di-methyl-amido-azo-benzene sulphonic acid	$N_2 \begin{cases} C_6H_4N(CH_3)_2 \\ C_6H_4.SO_3H \end{cases}$	"	"
Phenyl-azo-phenyl-β-naphthol-sulphonic acid (Croceine Scarlet)	$Ph.N:N.C_6H_4.N:N.C_{10}H_5(HSO_3)OH$ β	One band	Hartley, *Chem. Soc. Trans.* 51 (1887), 153.
Tri-amido-azo-benzene	$N_2 \begin{cases} C_6H_3(NH_2)_2 \\ C_6H_4.NH_2 \end{cases}$	Selective	Landauer, *Ber.* 14 (1881), 391.

B

Substance	Formula	Nature of Absorption	Reference
Benzene	C_6H_6	Six bands	Hartley and Huntington, *Phil. Trans.* II. (1879), 257; Hartley, *Chem. Soc. Trans.* 47 (1885), 685; Hartley and Dobbie, *Chem. Soc. Trans.* 73 (1898), 695; Pauer, *Wied. Ann. der Phys.* 61 (1897), 363.
Benzene-hexa-chloride	$C_6H_6Cl_6$	Highly diactinic	Hartley, *Chem. Soc. Trans.* 39 (1881), 153.
Benzene-methyl	See *Toluene.*		
Benzene-tetra-hydro	See under T.		
Benzoic Acid	$C_6H_5.COOH$	Selective	Hartley and Huntington, *Phil. Trans.* I. (1879), 257.
Benz-aldoxime (*anti-*)	$C_6H_5.C.H$ ‖ $OH.N$	One band	Hartley and Dobbie, *Chem. Soc. Trans.* 77 (1900), 509.
iso-Benz-aldoxime (*syn.* aldoxime)	$C_6H_5.C.H$ ‖ $N.OH$	"	"
Benzene-azo-β-naphthol-sulphonic acid	See under *Azo Compounds.*		
Benzyl diphenyl-amine—Violet	—	Selective	Lemoult, *Compt. Rend.* 131 (1900), 839.
Biebrich Scarlet (Sodium Salt)	$HSO_3.C_6H_4.N_2.C_6H_4(HSO_3).N_2.C_{10}H_6.OH$ β	One band	Hartley, *Chem. Soc. Trans.* 51 (1887), 153.
Bismarck Brown Triamidoazo-benzene	$C_6H_4.NH_2.N:N.C_6H_3(NH_2)_2$	"	"
Biuret	$C_2H_5N_3O_2$	Continuous	J. L. Soret, *Archives des sciences physiques et naturelles,* 1893 (3rd Series), 429.
Brilliant Green	$PhC:\{C_6H_4N(Et)_2\}_2$ OH	Selective	Lemoult, *Compt. Rend.* 131 (1900), 839.
Brom-benzene	$C_6H_5.Br$	"	Pauer, *Wied. Ann. der Phys.* 61 (1897), 363.
Brucine	$C_{23}H_{26}N_2O_4 + 4H_2O$	"	Hartley, *Phil. Trans* II. (1885), 471.

APPENDIX—*cont.*

Substance	Formula	Nature of Absorption	Reference
iso-Butylic Acetate	$CH_3COO.C_4H_9$	Continuous	Hartley and Huntington, *Phil. Trans.* II. (1879), 257.
iso-Butylic Butyrate	$C_3H_7.COO.C_4H_9$	"	"
iso-Butylic Formate	$HCOO.C_4H_9$	"	"
iso-Butylic Valeranate	$C_5H_9O_2.C_4H_9$	"	"
Butyric Acid	$CH_3.CH_2.CH_2.COOH$	"	"
Butyric Acid—Barium salt of	$(C_3H_7COO)_2Ba$	"	"
Butyric Acid—Sodium salt of	$C_3H_7COO.Na$	"	"
iso-Butyric acid	$(CH_3)_2:CH.COOH$	"	"
C			
Caffeine	$C_8H_{10}N_4O_2$	General	Hartley, *Phil. Trans.* II. (1885), 471.
Camphor	$C_{10}H_{16}O$	Highly diactinic	Hartley, *Chem. Soc. Trans.* 39 (1881), 153
Camphoric Acid	$C_8H_{14}(COOH)_2$	General	"
Carbohydrates:			
Cane Sugar	$C_{12}H_{22}O_{11}$	"	J. L. Soret, *Archives des sciences physiques et naturelles,* 1893 (3rd Series), 429.
		Highly diactinic	Hartley, *Trans. Chem. Soc.* 51 (1887), 58.
Glucose	$C_6H_{12}O_6$	General	J. L. Soret, *Archives des sciences physiques et naturelles,* 1893 (3rd Series), 429. Also Hartley.
o-Oxy-carbanil	See under O.		
Carbon disulphide	CS_2	Selective	Pauer, *Wied. Ann. der Phys.* 61 (1897), 363.
Carbon disulphide vapour	—	"	Pauer, *Wied. Ann. der Phys.*, 61 (1897), 363.
Carbon disulphide solution	—	"	
Carbostyril	C_9H_7NO	One band	Hartley and Dobbie, *Chem. Soc. Trans.* 75 (1899), 640.
Methyl Carbostyril	$C_{10}H_9NO$	"	"
Methyl pseudo-Carbostyril	$C_{10}H_9NO$	"	"
Cevadine (Merk's Veratrin)	$C_{32}H_{49}NO_9$ (?)	General	Hartley, *Phil. Trans.* II. (1885), 471.
Chlor-benzene	C_6H_5Cl	Selective	Pauer, *Wied. Ann. der Phys.* 61 (1897), 363.
Chrysazin	$C_6H_2(CO)_2C_6H_2(OH)_2$	"	Libermann and Kostanecki, *Ber.* 19 (1886), 2327.
Chrysoidine (Diamido-azo-benzene)	See *Azo Compounds.*		
Cinchonine sulphate	$(C_{19}H_{22}N_2O)_2.H_2SO_4+2H_2O$	"	Hartley, *Phil. Trans.* II. (1885), 471.
Chinconidine sulphate	$(C_{19}H_{22}N_2O)_2H_2SO_4+6H_2O$	"	"

APPENDIX—*cont.*

Substance	Formula	Nature of Absorption	Reference
Codeine	$C_{18}H_{21}NO_3$	Selective	Hartley, *Phil. Trans.* II. (1885), 471.
Codeine di-acetyl	$C_{13}H_{19}(C_2H_3O)_2NO_3$	„	„
Corallin	—	„	Vogel, *Ber.* 11 (1878), 1363.
Cotarnine hydrobromide	$C_{12}H_{15}NO_4.HBr+2H_2O$	„	Hartley, *Phil. Trans.* II. (1885), 471.
Croceine Scarlet (Phenyl - azo-phenyl-β-naphthol-sulphonic acid)	See under *Azo Compounds.*		
o-Cresol	$C_6H_4(CH_3)OH$	„	Hartley, *Chem. Soc. Trans.* 53 (1888), 641.
m-Cresol	$C_6H_4(CH_3)OH$	„	„
p-Cresol	$C_6H_4(CH_3)OH$	„	„
Cumeneazo - β - naphthol-disulphonic acid (Sodium Salt)	$C_9H_{11}.N{:}N.C_{10}H_4(HSO_3)_2OH\beta$	One band	Hartley, *Chem. Soc. Trans.* 51 (1887), 158.
Cyanin	—	Selective	Vogel, *Ber.* 11 (1878), 1363.
Cyanogen—Hydrocyanic Acid	See under H.		
Cyanuric Acid	$C_3N_3(OH)_3$	General	Hartley, *Chem. Soc Trans.* 41 (1882), 45; Hartley, Dobbie and Lauder, *Chem. Soc. Trans.* (1901).
iso-Cyanuric Acid —Methylic ester of	See *Methyl iso-cyanurate.*		
Cyanuric Acid—Methylic ester of	See *Methyl cyanurate.*		
Cyanuric Chloride	$C_3N_3Cl_3$	„	Hartley, Dobbie and Lauder, *Chem. Soc. Trans.* (1901).
D			
di-Acetyl Codeine	See under *Codeine.*		
α-Ethylic di-benzoyl succinate	See under E.		
β-Ethylic di-benzoyl succinate	See under E.		
γ-Ethylic di-benzoyl succinate	See under E.		
Di - amido - azo - benzene (Chrysoidene)	See *Azo Compounds.*		
Di-ethylamine	$NH(C_2H_5)_2$	Continuous	Hartley and Hunting ton, *Phil. Trans* I. (1879), 257.
Digitaline	$C_{29}H_{46}O_{12}$	„	Hartley, *Phil. Trans* II. (1885), 471.
Diketo hexamethylene	$CO\langle{CH_2.CH_2 \atop CH_2.CH_2}\rangle CO$	„	Hartley and Dobbie *Chem. Soc. Trans* (1898), 599.
Di-methyl-amido-azo-benzene	See *Azo Compounds.*		
Dimethylamine	$NH(CH_3)_2$	„	Hartley and Hunting ton, *Phil. Trans.* I (1879), 257.

APPENDIX—*cont.*

Substance	Formula	Nature of Absorption	Reference
Dimethyl pyrazine	$C_6H_8N_2$	One band	Hartley and Dobbie, *Chem. Soc. Trans.* 77 (1900), 846.
m-Dioxyanthraquinone [1:2]		Selective	Libermann and Kostanecki, *Ber.* 19 (1886), 2327.
Dipyridine	$C_{10}H_{10}N_2$	One band	Hartley, *Chem. Soc. Trans.* 47 (1885), 685.
E			
Emodin	$C_{14}H_8O_5$	Selective	Libermann and Kostanecki, *Ber.* 19 (1880), 2327.
Eosin	$C_{20}H_8Br_4O_5$	"	Vogel, *Ber.* 11 (1878), 1363; E. Vogel, *Wied. Ann.* 43, New Series (1891), 449.
Ethylamine 33 %	$NH_2(C_2H_5)$	Continuous	Hartley and Huntington, *Phil. Trans.* I. (1879), 257.
Ethyl-benzene	$C_6H_5(C_2H_5)$	Selective	" Pauer, *Wied. Ann. der Phys.* 61 (1897), 336.
Ethylene Gas	C_2H_4	Highly diactinic	Hartley, *Chem. Soc. Trans.* 39 (1881), 153.
Ethylic Alcohol	$C_2H_5.OH$	"	Hartley and Huntington, *Phil. Trans.* I. (1879), 257; Schönn, *Wied. Ann.* 6, New Series (1879), 267.
Ethylic Acetate	$CH_3.COO.C_2H_5$	Continuous	"
Ethylic Butyrate	$C_3H_7COO.C_2H_5$	"	"
Ethylic Formate	$H.COO.C_2H_5$	"	"
Ethylic Isocyanate	$CO.N.C_2H_5$	"	Hartley, Dobbie and Lauder, *Chem. Soc. Trans* (1901).
Ethylic Propionate	$C_2H_5.COO.C_2H_5$	"	Hartley and Huntington, *Phil. Trans.* I. (1879), 257.
Ethylic Valerate	$C_3H_9O_2.C_2H_5$	"	"
Ethylic ether of o-oxycarbanil (enolic form, B.P. 225°-230°)	See under O.		
Ethylic ether of o-oxycarbanil (ketonic form, M.P. 29°)	See under O.		
α-Ethylic dibenzoyl succinate	$C_{22}H_{22}O_6$	One band	Hartley and Dobbie, *Chem. Soc. Trans.* 77 (1900), 498.
β-Ethylic dibenzoyl succinate	$C_{22}H_{22}O_6$		
γ-Ethylic dibenzoyl succinate	$C_{22}H_{22}O_6$		
F			
Fast Red (Sodium Salt)	$HSO_3.C_{10}H_6.N:N.C_{10}H_6.OH$ (α, β)	One band	Hartley, *Chem. Soc. Trans.* 51 (1887), 158.

APPENDIX—*cont.*

Substance	Formula	Nature of Absorption	Reference
Flavo-purpurin	$C_6H_3(OH)\left\langle{CO \atop CO}\right\rangle C_6H_2(OH)_2$ [1 : 2 : 6]	Selective	Libermann and Kostanecki, *Ber.* 19 (1886), 2327; Liebermann, *Ber.* 21 (1887), 2527.
Fluorescein	$C_{20}H_{12}O_5$	,,	Krüss, *Ber.* 18 (1885), 2586; E. Vogel, *Wied. Ann.* 43, New Series (1891), 449.
Fluorescein—Derivatives of	—	,,	Krüss; E. Vogel, *loc. cit.*
Formic Acid	H.COOH	Continuous	Hartley and Huntington, *Phil. Trans.* I. (1879), 257.
Formic Acid—Barium Salt of	$(HCOO)_2Ba$		
Fuchsin	$C_{20}H_{19}N_3.HCl+4H_2O$	Selective	Melde, *Pogg. Ann.* 126 (1865), 264; Vogel, *Ber.* 11 (1878), 1363.
p-Fuchsin	$C_6H_5\underset{\mid \atop Cl}{C}=(C_6H_4NH_2)_2$	,,	Krüss, *Ber.* 15 (1882), 1243.
Furfuraldehyde	$C_4H_3O.COH$	Continuous	Hartley and Dobbie, *Chem. Soc. Trans.* (1898), 599.
Furfuramide	$(C_4H_3O.CH_3)_3N_2$	,,	,,
Furfuran	$\begin{matrix}CH{:}CH \\ \mid \\ CH{:}CH\end{matrix}\!\!>\!O$	,,	,,

G

Glucose	See under *Carbohydrates.*		

H

Helianthine (Tropœoline O)	$HSO_3.C_6H_4.N{:}N.C_6H_4N(CH_3)_2$ (4) (4) (1)	Selective	Hartley, *Chem. Soc. Trans.* 51 (1887), 153.
Heptane	C_7H_{16}	Continuous	Hartley and Huntington, *Phil. Trans.* I. (1879), 257.
Hexane	C_6H_{14}	,,	,,
Hexamethylene	$C_6H_6.H_6$	,,	Hartley and Dobbie, *Chem. Soc. Trans.* 77 (1900), 846.
Hexamethylated Violet (Crystal Violet)	$(Me_2NC_6H_4)_2=\overset{\mid}{C}.C_6H_4.\overset{\mid\ \ \mid}{N}.Me_2$ (Cl)	Selective	Lemoult, *Compt. Rend.* 131 (1900), 839.
Hippuric Acid	$C_9H_9NO_3$	Continuous	Hartley and Huntington, *Phil. Trans.* I. (1879), 257; J. L. Soret, *Archives des sciences physiques et naturelles*, 1898 (3rd Series), 429.
Hofmann's Violet	$C_{20}H_{16}(CH_3)_3N.2HCl$	Three bands	Hartley, *Trans.* 51 (1887), 153.
Hydrocyanic Acid	HCN	Continuous	Hartley, *Trans.* 41 (1882), 45.
Hydroquinone	See under *Quinone*		
m-Hydroxybenzoic Acid	$C_6H_4(OH)COOH$	Selective	Hartley, *Chem. Soc. Trans.* 53 (1888), 641.

APPENDIX—*cont.*

Substance	Formula	Nature of Absorption	Reference
p-Hydroxybenzoic Acid . .	$C_6H_4(OH)COOH$	Selective	Hartley, *Chem. Soc. Trans.* 53 (1888), 641.
Hydroxylamine hydrochloride	$NH_2(OH).HCl$	Highly diactinic	Hartley and Dobbie, *Chem. Soc. Trans.* 77 (1900), 318.
Hyoscyamine .	$C_{17}H_{23}NO_3$	Continuous	Hartley, *Phil. Trans.* II. (1885), 471.
Hypoxanthine (Sarcine) . .	$C_5H_4N_4O$	Selective	J. L. Soret, *Archives des sciences physiques et naturelles*, 1893 (3rd Series), 429.
I			
Indigo . . .	$C_6H_4\left\langle{CO \atop NH}\right\rangle C=C\left\langle{CO \atop NH}\right\rangle C_6H_4$.	Selective	Vogel, *Ber.* 11 (1878), 1363; Krüss, *Ber.* 18 (1885), 2586.
Indigo — Derivatives of .	—	„	Krüss, *Ber.* 18 (1885), 2586.
Iodo-benzene .	C_6H_5I	„	Pauer, *Wied. Ann. der Phys.* 61 (1897), 363.
Iodine Green (Tri-methyl-rosaniline di-methyl-di-iodide)	$\begin{matrix} CH_3.HN.C_6H_4\diagdown & & \diagup N.CH_3 \\ & C & & \cdot 2CH_3I \\ CH_3.HN.C_6H_4\diagup & & \diagdown C_6H_3.CH_3 \end{matrix}$.	Four bands	Hartley, *Chem. Soc. Trans.* (1887), 153.
Isatin . . .	$C_8H_5NO_2$	Two bands	Hartley and Dobbie, *Chem. Soc. Trans.* 75 (1899), 640.
Methyl Isatin .	$C_9H_7NO_2$	One band	„
Methyl pseudo-Isatin . .	$C_9H_7NO_2$	Two bands	„
Iso Compounds .	See under substance to which *Iso* is prefixed.		
Iodobenzene Vapour	C_6H_5I	Selective	
Iodobenzene Solution . .	—	Continuous	
J			
Jap-aconitine .	See *Aconitine*.		
L			
Leucine . .	$C_6H_{13}NO_2$	Continuous	J. L. Soret, *Archives des sciences physiques et naturelles*, 1893 (3rd Series), 429.
M			
Malachite Green .	$\begin{matrix} C_6H_5.C=\{C_6H_4N(CH_3)_2\}_2 \\ \vert \\ OH \end{matrix}$	Selective	Lemoult, *Compt. Rend.* 131 (1900), 839; Vogel *Ber.* 11 (1878), 1363.
Melamine . .	$C_3N_3(NH_2)_3$	Continuous	Hartley, Dobbie, and Lauder, *Chem. Soc. Trans.* (1901).
Melamine — Triethyl ester of	See under *Tri-ethyl melamine*.		

APPENDIX—*cont.*

Substance	Formula	Nature of Absorption	Reference
iso - Melamine — Tri-ethyl ester of	See under *Tri-ethyl-iso-melamine.*		
Mesitylene . .	See *Tri-methyl Benzene.*		
Methylamine 33 %	$NH_2(CH_3)$	Continuous	Hartley and Huntington, *Phil. Trans.* I. (1879), 257.
Methylamine hydrochloride	$CH_3.NH_2.HCl$	Highly diactinic	Hartley and Dobbie, *Chem. Soc. Trans.* 77 (1900), 818.
Methylic Alcohol	$CH_3.OH$	"	Hartley and Huntington, *Phil. Trans.* (1879); Schönn, *Wied. Ann.* 6, (1879), 267.
Methyl Carbostyril	See under C.		
Methyl pseudo-Carbostyril	" "		
Methyl Green .	$C_6H_4.N.Me_2.MeCl$ $Me_2.N.C_6H_4.C—C_6H_4.N.Me_2$ . . Cl	Selective	Lemoult, *Compt. Rend.* 131 (1900), 889.
Methyl Isatin .	See under I.		
Methyl pseudo-Isatin	" "		
Methyl Pyridine .	See *Picoline.*		
Methylic Acetate	$CH_3.COO.CH_3$	Continuous	Hartley and Huntington, *Phil. Trans.* I. (1879), 257.
Methylic Alcohol	$CH_3.OH$	Highly diactinic	"
Methylic Butyrate	$C_3H_7.COO.CH_3$	Continuous	"
Methylic Cyanurate (M.P. 135°)	$C_3N_3(OCH_3)_3$	"	Hartley, Dobbie, and Lauder, *Chem. Soc. Trans.* (1901).
Methylic Formate	$H.COO.CH_3$	"	Hartley and Huntington, *Phil. Trans.* I. (1879), 257.
Methylic Isocyanate	$CON.CH_3$	"	Hartley, Dobbie, and Lauder, *Chem. Soc. Trans.* (1901).
Methyl Iso-cyanurate (M.P. 175°)	$C_3O_3N_3(CH_3)_3$	"	"
Methylic Propionate	$C_2H_5.COO.CH_3$	"	Hartley and Huntington, *Phil. Trans.* I. (1879), 257.
Methylic Salicylate	$C_6H_4(OH).COO.CH_3$	Selective	"
Methylic Valerate	$C_5H_9O_2.CH_3$	Continuous	"
Methyl Violet [Penta-methyl Violet ?]	$C_{19}H_{12}N_3(CH_3)_5HCl$	Selective	Vogel, *Ber.* 11 (1878), 1368.
Morphine . .	$C_{17}H_{19}NO_3$	"	Hartley, *Phil. Trans.* II. (1885), 471.
apo-Morphine .	See under A.		
Methyl Morphine	See *Codeine.*		
Morphine - tetracetyl	$C_{17}H_{15}(C_2H_3O)_4NO_3$	"	"
Murexide . .	$C_8H_4NH_4.N_5O_6 + H_2O$	Three bands	Hartley, *Chem. Soc. Trans.* 51 (1887), 153.

APPENDIX—*cont.*

Substance	Formula	Nature of Absorption	Reference
	N		
Naphthalene	$C_{10}H_8$	Four bands	Hartley, *Chem. Soc. Trans.* 39 (1881) 153; 47 (1885), 685
Naphthalene Red (Magdala Red)	$C_{30}H_{21}N_3.HCl.H_2O$	Selective	Vogel, *Ber.* 11 (1878) 622.
Naphthalene Red?	$C_{30}H_{20}N_4$	—	—
Naphthalene amido-azo-α-	See under *Azo Compounds.*		
Narceïne	$C_{23}H_{27}NO_8$	Continuous	Hartley, *Phil. Trans.* II. (1885), 471.
Narcotine	$C_{22}H_{23}NO_7$	Selective	"
oxy-Narcotine	See under O.		
Nicotine	$C_{10}H_{14}N_2$	Continuous	Hartley, *Phil. Trans.* II. (1885), 471.
m-Nitraniline	$C_6H_4(NO_2).NH_2$	Selective	Hartley and Huntington, *Phil. Trans.* I. (1879), 257.
p-Nitraniline	$C_6H_4(NO_2)NH_2$	"	"
Nitro-benzene (vapour)	$C_6H_5NO_2$	Continuous	Pauer, *Wied. Ann. der Phys.* 61 (1897), 363.
Nitro-benzene (solution)	—	"	—
o-Nitrophenol	$C_6H_4(OH)NO_2$	Selective	Hartley and Huntington, *Phil. Trans.* I. (1897), 257.
p-Nitrophenol	$C_6H_4(OH)NO_2$	"	"
Nitroso - diethyl aniline	$C_6H_4(NO)N(C_2H_5)_2$	"	Kock, *Wied. Ann.* 32 (1887), 167.
Nitroso-dimethyl aniline	$C_6H_4(NO)N(CH_3)_2$	"	"
Nitroso-ethyl aniline	$C_6H_5N(NO)C_2H_5$	"	"
Nitroso-iso-butyl aniline	$C_6H_5N(NO)C_4H_9$	"	"
Nitroso - methyl aniline	$C_6H_5N(NO)CH_3$	"	"
Nitroso - prophyl-aniline	$C_6H_5N(NO)C_3H_7$	"	"
Nitroso-di-phenylamine	$(C_6H_5)_2N.NO$	"	"
Nitroso - di - methyl m-chlor-aniline	$C_6H_3Cl(NO)N(CH_3)_2$	"	"
Nitroso - di - methyl - m - brom-aniline	$C_6H_3Br(NO)N(CH_3)_2$	"	"
Nitroso - di - methyl-m-iod-aniline	$C_6H_3I(NO)N(CH_3)_2$	"	"
Nitroso-ethyl-α-naphthylamine	$C_{10}H_7N(NO)C_2H_5$	"	"
Nitroso-ethyl-o-toluidine	$C_6H_4.CH_3.N(NO)C_2H_5$	"	"
Nitroso-methyl-o-toluidine	$C_6H_4.CH_3N(NO)CH_3$	"	"

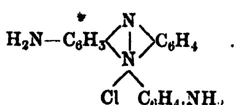
APPENDIX—*cont.*

Substance	Formula	Nature of Absorption	Reference
	O		
Octane . .	C_8H_{18}	Continuous	Hartley and Huntington, *Phil. Trans.* I. (1879), 257.
Octylic Alcohol .	$C_8H_{17}.OH$	,,	,,
Oxalic Acid (10 % solution)	$\begin{matrix}COOH\\ \vert \\COOH\end{matrix}$	,,	,,
Oxaluric Acid .	$CO\langle\begin{matrix}NH_2\\NH.CO.COOH\end{matrix}$	Selective	J. L. Soret, *Archives des sciences physiques et naturelles*, 3rd Series (1893), 429.
o-Oxybenzoic Acid (see *Salicylic Acid*)	$C_6H_4(OH)COOH$	,,	Hartley, *Trans. Chem. Soc.* 53 (1888), 641.
m - Oxy - benzoic Acid (1.3)	$C_6H_4(OH)COOH$	,,	Hartley and Huntington, *Phil. Trans.* I. (1879), 257.
p - Oxy - benzoic Acid	$C_6H_4(OH)COOH$	,,	,,
o-Oxy-carbanil .	$C_7H_5O_2N$	One band	Hartley, Dobbie and Paliatseas, *Chem. Soc.Trans.* 77 (1900), 839.
o-Oxycarbanil — Ethylic ether of (enolic form, B.P. 225°–230°)	$C_9H_9O_2N$	,,	,,
o-Oxycarbanil — Ethylic ether of (ketonic form, M.P. 29°)	$C_9H_9O_2N$	,,	,,
Oxy-narcotine .	$C_{22}H_{23}NO_8$	Selective	Hartley, *Phil. Trans.* II. (1885), 471.
Ozone . . .	O_3	,,	Hartley, *Chem. Soc. Trans.* 39 (1881), 57.
	P		
Paparerine . .	$C_{20}H_{21}NO_4$	Selective	Hartley, *Phil. Trans.* II. (1885), 471.
Penta - methyl-para-rosaniline	$(CH_3)N{-}C_6H_4{-}C\langle\begin{matrix}C_6H_4N(CH_3)_2\\C_6H_4N(CH_3)_2\end{matrix}$		
Phenanthrene .	$C_{14}H_{10}$	Four bands	Hartley, *Chem. Soc. Trans.* 39 (1881), 153.
Phenol . .	C_6H_5OH	Selective	Hartley and Huntington, *Phil. Trans.* I. (1879), 257; Schönn, *Wied. Ann.* 6, New Series (1879), 267.
Phenyl Blue .	—	,,	Lemoult, *Compt. Rend.* 131 (1900), 839.
Phlorizine . .	$C_{21}H_{24}O_{10}$	,,	Hartley and Huntington, *Phil. Trans.* I. (1879), 257.
Phthalic Acid .	$C_6H_4(COOH)_2$	,,	,,
Picoline (Methyl Pyridine)	$C_5H_4N(CH_3)$	,,	Hartley, *Chem. Soc. Trans.* 41 (1882), 45; 45 (1885), 685.
Picric Acid . .	—	,,	Melde, *Pogg. Ann.* 126 (1865), 264.

APPENDIX—*cont.*

Substance	Formula	Nature of Absorption	Reference
Picrotoxine	$C_{30}H_{34}O_{13}$	Continuous	Hartley, *Phil. Trans.* II. (1885), 471.
Piperidine	$C_5H_{11}N$	"	Hartley, *Chem. Soc. Trans.* 47 (1885), 685.
Piperine	$C_{17}H_{19}NO_3$	Selective	Hartley, *Phil. Trans.* II. (1885), 471.
Potassium Cyanate	KCNO	Continuous	J. L. Soret, *Archives des sciences et naturelles*, 3rd Series (1893), 429; Hartley, Dobbie and Lauder, *Chem. Soc. Trans.* (1901).
Propionic Acid	C_2H_5COOH	"	Hartley and Huntington, *Phil. Trans.* I. (1879), 257.
Propionic Acid—Barium salt of	$(C_2H_5COO)_2Ba$	"	"
Propionic Acid—Sodium salt of	C_2H_5COONa	"	"
Propylic Alcohol	C_3H_7OH	"	"
Propylic Formate	$HCOO.C_3H_7$	"	"
Propylic Propionate	$C_2H_5COO.C_3H_7$	"	"
Propylic Valeranate	$C_5H_9O_2.C_3H_7$	"	"
Purpurin	$C_6H_4\langle{}^{CO}_{CO}\rangle C_6H(OH)_3 + H_2O$ $[(OH)_3\ 1:2:4]$	Selective	Vogel, *Ber.* 11 (1878), 1368; Libermann and Kostanecki, *Ber.* 19 (1886), 2327.
Purpuro-xanthin	$C_6H_4(CO)_2C_6H_2(OH)_2\ [1:3]$	"	Libermann and Kostanecki, *Ber.* 19 (1886), 2327.
Pyrazine - di - methyl	See under D.		
Pyridine	C_5H_5N	One band	Hartley, *Chem. Soc. Trans.* 47 (1885), 685; Hartley and Dobbie, *Chem. Soc. Trans.* 77 (1900), 318; Pauer, *Wied. Ann. der Phys.* 63 (1897), 363.
Pyridine hydrochloride	$C_5H_5N.HCl$	"	Hartley, *Chem. Soc. Trans.* 47 (1885), 685.
Pyridine 2.5 dicarboxylic acid (*iso* - cinchomeronic acid)	$C_5H_3N(COOH)_2$	Selective	Hartley, *Chem. Soc. Trans.* 41 (1882), 45.
Pyrocatechol	$C_6H_4(OH)_2$	"	Hartley, *Chem. Soc. Trans.* 53 (1888), 641.
Pyrogallol	$C_6H_3(OH)_3$	"	Hartley and Huntington, *Phil. Trans.* I. (1879), 257.
Pyromucic Acid	$C_4H_3O.COOH$	Continuous	"
Pyrrole (Pyrroline)	$\begin{matrix} CH{:}CH \\ \vert \\ CH{:}CH \end{matrix}\!\!\!>NH$	"	Hartley and Dobbie, *Chem. Soc. Trans.* (1898), 599.

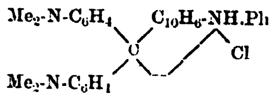
APPENDIX—*cont.*

Substance	Formula	Nature of Absorption	Reference
	Q		
Quinidine sulphate	$(C_{20}H_{24}N_2O_2)_2H_2SO_4$	Selective	Hartley, *Phil. Trans.* II. (1885), 471.
Quinine . .	$C_{20}H_{24}N_2O_2$	"	"
Quinine sulphate	$(C_{20}H_{24}N_2O_2)H_2SO_4$	"	"
Quinizarin . .	$C_6H_4(CO)_2C_6H_2(OH)_2$ [1 : 4]	"	Libermann and Kostanecki, *Ber.* 19 (1886), 2827; Liebermann, *Ber.* 21 (1887), 2527.
Quinone . .	$C_6H_4(OH)_2$	"	Hartley, *Chem. Soc. Trans.* 53 (1888), 641; J. L. Soret, *Archives des sciences physiques et naturelles*, 3rd Series (1893), 429.
Quinoline . .	C_9H_7N	"	Hartley, *Chem. Soc. Trans.* 41 (1882), 45; 47 (1885), 685.
Quinoline hydrochloride	$C_9H_7N.HCl$	"	"
Tetra-hydro-quinoline	$C_9H_{11}N$	One band	"
Tetra-hydro-quinoline hydrochloride	$C_9H_{11}N.HCl$	"	"
	R		
Resorcinol . .	$C_6H_4(OH)_2$ (1 : 3)	Selective	Hartley, *Chem. Soc. Trans.* 53 (1888), 641.
Rosaniline (base)	$\begin{matrix} H_2N.C_6H_4 \\ H_2N.C_6H_4 \end{matrix} \rangle C \langle \begin{matrix} C_6H_3(CH_3).NH_2 \\ OH \end{matrix}$.	Three bands	Hartley, *Chem. Soc. Trans.* 51 (1887), 153.
Rosaniline hydrochloride	$C_{20}H_{20}N_3Cl$	Two bands	"
Rosolic Acid .	$C_{20}H_{16}O_3$	Selective	Krüss, *Ber.* 18 (1885), 2586.
Rufigallic Acid .	$C_{14}H_2O_2(OH)_6$ [1 : 2 : 3 : 5 : 6 : 7]	"	Libermann, *Ber.* 21 (1887), 2527.
	S		
Saffranine . .	 . . .	Selective	Landauer, *Ber.* 11 (1878), 1772.
Salicylic Acid (5 % solution)	$C_6H_4(OH)(COOH)$	"	Hartley and Huntington, *Phil. Trans.* I. (1879), 257; Hartley, *Chem. Soc. Trans.* 53 (1888), 641.
Salicine . .	$C_{13}H_{18}O_7$	"	"
Santalin . .	$C_{15}H_{14}O_5$	"	Vogel, *Ber.* 11 (1878), 1363.
Sarcine . .	See under *Hypoxanthin*		
Serine . . .	$C_3H_7NO_3$	Continuous	J. L. Soret, *Archives des sciences physiques et naturelles*, 3rd Series (1893), 429.
Sodium Carbonate	Na_2CO_3	"	

APPENDIX—*cont.*

Substance	Formula	Nature of Absorption	Reference
Solanine	$C_{52}H_{93}NO_{18}$ (?)	Continuous	Hartley, *Phil. Trans.* II. (1885), 471.
Strychnine	$C_{21}H_{22}N_2O_2$	Selective	„
	T		
Tetracetyl morphine	See under *Morphine*.		
Tetrahydrobenzene	$C_6H_6H_4$	Continuous	Hartley and Dobbie, *Chem. Soc. Trans.* 77 (1900), 846.
Thebaïne	$C_{19}H_{21}NO_3$	Selective	Hartley, *Phil. Trans.* II. (1885), 471.
Thiophene	$\begin{array}{l} CH{:}CH \\ \vert \qquad\quad \rangle S \\ CH{:}CH \end{array}$	Strong continuous	Hartley and Dobbie, *Chem. Soc. Trans.* (1898), 599; Pauer, *Wied. Ann. der Phys.* 61 (1897), 363.
Thymol	$\underset{1}{C_6H_3}(\underset{4}{CH_3})(\underset{3}{C_3H_7})OH$	Selective	Hartley and Huntington, *Phil. Trans.* (1879), I. 257.
Toluene	$C_6H_5CH_3$	„	Hartley and Huntington, *Phil. Trans.* (1879), I. 257; Pauer, *Wied. Ann. der Phys.* 61 (1897), 363.
o-Toluidine Hydrochloride	$C_7H_7.NH_2.HCl$	„	Hartley, *Chem. Soc. Trans.* 47 (1885), 685.
p-Toluidine	$C_7H_7.NH_2$	„	„
Tri-amido-azobenzene	See *Azo Compounds.*		
Tri-ethylamine	$N(C_2H_5)_3$	Continuous	Hartley and Huntington, *Phil. Trans.* I. (1879), 257.
Tri-ethylmelamine (M.P. 74°)	$C_3N_6H_3(C_2H_5)_3$	„	Hartley, Dobbie, and Lauder, *Chem. Soc. Trans.* (1901).
Tri-ethyl-*iso*-melamine (M.P. 92°)	$C_3N_6H_3(C_2H_5)_3$	„	„
Tri-methylamine	$N(CH_3)_3$	„	Hartley and Huntington, *Phil. Trans.* I. (1879), 257.
Tri-methyl benzene (1 : 3 : 5) (Mesitylene)	$C_6H_3(CH_3)_3$	Selective	„
Trimethyl-rosaniline di-methyl-di-iodide	See *Iodine Green.*		
Triphenylmethane	$CH(C_6H_5)_3$	„	Hartley, *Chem. Soc. Trans.* 51 (1887), 153.
Tropœoline O	See *Helianthine.*		
Tropœoline OOO	No. 1. $\underset{a}{OH.C_{10}H_6}.N{:}N.C_6H_4.SO_3Na$	One band	„
	No. 2. $\underset{\beta}{OH.C_{10}H_6}.N{:}N.C_6H_4.SO_3Na$	„	„
Tyrosine	$C_9H_{11}NO_3$	Selective	Hartley and Huntington, *Phil. Trans.* I. (1879), 257; J. L. Soret, *Archives des sciences physiques et naturelles*, 3rd Series (1898), 429.

APPENDIX—*cont.*

Substance	Formula	Nature of Absorption	Reference
	U		
Urea . .	$CO(NH_2)_2$	Continuous	J. L. Soret, *Archives des sciences physiques et naturelles*, 3rd Series (1898), 429; Hartley, *loc. cit.*
Uric Acid . .	$C_5H_4N_4O_3$	Selective	J. L. Soret, *loc. cit.*; Hartley, *Chem. Soc. Trans.* 51 (1887), 153.
	V		
Veratrin . .	$C_{32}H_{49}NO_9$	Selective	Hartley, *Phil. Trans.* II. (1885), 47
Victoria Blue .		„	Lemoult, *Compt. Rend.* 131 (1900), 839.
	W		
Distilled Water .	H_2O	Highly diactinic	Hartley and Huntington, *Phil. Trans.* I. (1879), 257.
	X		
Xanthine hydrochloride	$C_5H_4N_4O_2.HCl$	Selective	J. L. Soret, *Archives des sciences physiques et naturelles*, Series (1898), 429.
p-Xylene . .	$C_6H_4(CH_3)_2$	Two bands	Hartley, *Chem. Soc. Trans.* 47 (1885), 685; Pauer, *Wied. Ann. der Phys.* 61 (1897), 368
m-Xylene	$C_6H_4(CH_3)_2$	One band	
o-Xylene	$C_6H_4(CH_3)_2$		

The Methods for the Determination of Hydrolytic Dissociation of Salt-Solutions. By R. C. FARMER, *Ph.D., M.Sc.*

[Ordered by the Council to be printed *in extenso.*]

IT is a matter of common experience that many salts, although containing equivalent quantities of acid and base, react acid or alkaline towards indicators in aqueous solution. If we take, for instance, a salt such as potassium cyanide and dissolve it in water, we find that, although it contains the amount of hydrocyanic acid theoretically necessary to neutralise the potassium hydrate, it reacts strongly alkaline, thus showing the presence of free potassium hydrate in the solution.

A very superficial observation shows that the solution also contains free hydrocyanic acid. Its presence is indeed rendered obvious by its characteristic smell. It is therefore evident that the potassium cyanide

has undergone a decomposition into free potassium hydrate and free hydrocyanic acid

$$KCN + HOH = KOH + HCN.$$

Similarly we find that other salts, as, for instance, ferric chloride, react acid in aqueous solution.

Even Rose,[1] who was probably the first to notice these phenomena, recognised that this was the result of a secondary reaction, which was brought about by the water. An analogy was sought in the decomposition of acid chlorides and the breaking up of organic complexes such as saccharose, in which the elements of water are taken up, and for this reason the name 'hydrolysis' was, rather unfortunately, applied indiscriminately to the two phenomena.

The nature of the decomposition formed the subject of considerable discussion, but it was not until Arrhenius brought the theory of electrolytic dissociation to bear on it that a satisfactory explanation was found. As this theory is almost universally accepted at the present time, it is not necessary to make more than a passing reference to a theory which at one time offered some opposition to that of Arrhenius. This was an assumption that the salts in question formed hydrates in aqueous solution, and that these hydrates possessed acid or basic properties.

Thus Werner[2] attempted to explain the acid reaction of copper chloride in aqueous solution on the assumption that it formed a hydrate of the formula $\begin{matrix} Cl \\ Cl \end{matrix}\!\!>\!Cu\!<\!\!\begin{matrix} H_2O \\ H_2O \end{matrix}$ which was acid in character. In this way, of course, it would be possible to account for the acid or alkaline reaction of all hydrolysed salts. Potassium cyanide would form a hydrate of a basic nature and so on.

It is an unsatisfactory feature of this theory that it makes the assumption of innumerable hydrates whose existence in aqueous solution is still to be proved; but apart from this it is shown that the acid or basic reaction is the result of a dissociation and not of a formation of hydrates by the fact that the acid and basic components can be easily separated. This separation can be sometimes effected by mere warming, as in the case of iron or aluminium acetate, in many other cases by dialysis.

In the case of diphenylamine hydrochloride repeated washing suffices to completely remove the hydrochloric acid, and in the case of many organic salts, as, for instance, sodium phenolate, one of the components can be partially removed by extraction with ether.

In 1890 Arrhenius[3] brought forward a simple explanation of the hydrolysis of salts on the basis of the theory of electrolytic dissociation. All that was necessary in order to bring the phenomenon of hydrolysis into complete harmony with the ionic theory was to consider water as an electrolyte, to suppose that it is to a slight extent dissociated into hydrogen and hydroxyl ions. Later investigations have completely justified this assumption. Compared with the weakest of acids, the ionisation of water is almost infinitesimal, but it has been determined with a considerable amount of accuracy. Water consists, then, of a solution of hydrogen and hydroxyl ions of such a strength that ten million litres of water contain approximately one gram equivalent of free ions. This means that water can act at the same time as a weak acid and a base.

[1] *Jahresber.*, 1852, 310. [2] *Zeitschr. für anorg. Chem.*, 9, 408.
[3] *Zeitschr. für phys. Chem.*, 5, 16 (1890).

Thus, when an acid and a base are brought together, the neutralisation never takes place quite completely. There always remain as many free hydrogen and hydroxyl ions over as are usually present in pure water. The quantity of ionised water is, of course, so small as to be practically negligible in most cases, but its effect becomes very marked when the acid or base of a dissolved salt is very weak.

If we take, for instance, a salt like potassium cyanide, its acid, hydrocyanic acid, is very weak, and is still further enormously weakened by the presence of its neutral salt, or, to put it in ionic language, by the presence of excess of cyanogen ions. The water is therefore by virtue of its slight acid properties capable of setting free a considerable quantity of the acid from its salt.

It might appear at first sight as if the solution should still react neutral, since the acid and base are set free in equivalent quantities. The theory of electrolytic dissociation shows us, however, that this is not the case. If we consider the equilibrium :

$$KCN + HOH \rightleftarrows KOH + HCN$$

the potassium hydrate exists practically completely in the ionised state, whereas the hydrocyanic acid is almost entirely unionised. Thus we have a large excess of hydroxyl ions in the solution, and it is these that give rise to the alkaline reaction. Expressed ionically the equilibrium will read

$$CN' + HOH \rightleftarrows HCN + OH'.$$

This theory of Arrhenius has now met with almost universal acceptance, and has amply justified its adoption as a working basis for all quantitative problems dealing with hydrolysis.

The conditions for the dissociation of a salt into free acid and base are therefore—

1. That the acid or base of the salt, or both, be very weak.
2. That the solvent itself be somewhat ionised.

Hitherto the phenomenon appears only to have been studied in aqueous solution. If the slight conductivities found for pure alcohol are really due to an ionisation into hydrogen- and ethoxy-ions, then we should expect salts such as sodium phenolate to be also split up to some extent in alcoholic solution.

For the qualitative detection of hydrolysis, indicators afford the most reliable test. From the results of Ley,[1] litmus appears to be the most sensitive of these.

Still, the method of simply testing the solution with an indicator might at times give misleading results owing to the presence of traces of acid or alkali in the salt. Ley recommends a more satisfactory method. This is to titrate the solution. If the salt of a weak base, for instance, is really hydrolysed, it will not only react acid in the pure state, but will also continue to react acid even on addition of a considerable quantity of alkali. Thus, whereas the least trace of sodium hydrate sufficed to render a solution of magnesium sulphate or barium chloride alkaline, solutions of lead chloride and copper chloride continued to react acid until almost the whole of the hydrochloric acid had been removed by the sodium hydrate.

As other qualitative methods any processes may be used which bring

[1] *Zeitschr. für phys. Chem.*, 30, 203 (1899).

bout a separation of the components. Thus, the hydrocyanic acid may be partially removed from a solution of sodium cyanide by a current of pure air, the phenol may be partially extracted from a solution of sodium phenolate by ether, and so on.

Quantitative Methods.—When we attack the problem of ascertaining quantitatively to what extent this hydrolytic dissociation of salts occurs, it is at once evident that the hydrolysis cannot be determined by any direct measurement of the free acid or alkali in the system. If we attempt to titrate the solution of a salt like potassium cyanide, the equilibrium is at once disturbed, and as we neutralise the free potassium hydrate in the system by the addition of acid, more potassium hydrate is supplied from the potassium cyanide to take its place. As we have seen, the neutral point is in many cases only reached when enough acid has been added to completely split up the salt. We must therefore resort to some indirect means of estimating the free acid or alkali in the system without disturbing the equilibrium.

We will pass over such methods as the determination of the heat of neutralisation, as these have led to very incorrect ideas as to the extent of the hydrolysis. For instance, determinations of the heat of neutralisation of hydrocyanic acid led to the belief that a solution of sodium cyanide was split up to the extent of 80 per cent. into free hydrocyanic acid and sodium hydrate, whereas in reality its hydrolysis only amounts to about 1 per cent. in $\frac{1}{10}$ normal solution.

In fact, the hydrolysis proves in most cases to be much smaller than was formerly imagined. Even salts like sodium phenolate, which react strongly alkaline, are only hydrolysed to the extent of 2 or 3 per cent. in about $\frac{1}{10}$ normal solution.

The quantitative methods which have hitherto been used are mostly based on the measurement of the velocity of reactions, brought about by the free alkali or acid in the solution. Of these reactions the chief have been the saponification of esters and the inversion of cane sugar.

Saponification of Esters.—If we take an ester such as ethyl acetate and dissolve it in pure water, it will remain for weeks practically unaffected. If, however, we add acid or alkali, saponification sets in, and proceeds with a velocity depending on the amount of acid or alkali added. The velocity can be measured by means of titrations.

If we treat the ester with a hydrolysed salt, saponification will likewise take place by virtue of the free acid or alkali which the solution contains. We must distinguish between the case in which the saponification is brought about by free acid and that in which it is brought about by alkali. The action of acids in saponifying esters is purely catalytic; the amount of acid remains unchanged throughout the reaction; this is, therefore, the simplest case, and we will consider it first.

For the measurement of the velocity, known quantities of ester and acid are brought together in aqueous solution and kept at constant temperature. At measured intervals of time a part of the solution is removed by means of a pipette and quickly titrated. This tells us how much of the ester has been converted to acetic acid and alcohol in a given time. From the results of these titrations the whole course of the reaction can be followed.

By the law of mass action, the velocity of the reaction at any moment is proportional to the product of the concentrations of the reacting substances (the ester and acid). The velocity diminishes, therefore, as the

ester is used up. If C_1 and C_2 be the two concentrations, and t be the time,

$$\text{Velocity} = -\frac{dC_1}{dt} = KC_1C_2, \text{ where K is a constant.}$$

If we always take the same amount of ester, the velocity of the reaction is proportional to the amount of acid added. The general method is therefore to determine by a preliminary experiment the velocity of saponification brought about by a known amount of pure acid, and afterwards to determine its velocity as brought about by the acid in the hydrolysed salt. If we have found the velocity of saponification brought about by a known quantity of acid, then we can conversely calculate from the velocity of saponification which the hydrolysed salt brings about, how much free acid it contains, that is, the extent of its hydrolysis, remembering always that the velocity of the reaction is proportional to the amount of free acid present.

It should be mentioned that this proportionality does not hold quite strictly in the catalysis of esters by means of acids. There are deviations from it which are not fully understood. It differs in strong and weak solutions of acids, apart from the difference which one would expect from incomplete ionisation. The presence of neutral salts also has a considerable influence on the velocity. Consequently the results obtained by this method are not to be taken as very accurate.

Since the velocity varies throughout the whole course of the reaction, we cannot take a direct measurement of the initial velocity of saponification, as the velocity changes so quickly that no trustworthy results could be obtained in this way. The calculation is carried out by means of the well known equation

$$K = \frac{1}{t} \log \frac{A}{A-x},$$

which holds for monomolecular reactions.

A is the initial concentration of the ester, x is the amount saponified in time t, and K is a constant. The titrations taken during the whole course of the reaction are used to determine K. By comparing the constant K obtained for the hydrolysed chloride of a weak base with that obtained for pure hydrochloric acid, the amount of free hydrochloric acid in the solution of the salt can be easily calculated, and hence the degree of hydrolysis.

The first experiments in this direction were carried out by Walker in 1889.[1] He determined the velocities of saponification of methyl acetate by the hydrochlorides of very weak bases, such as thiazol, and thus determined the degrees of hydrolysis.

A similar method was worked out for the salts of very weak acids by Shields, in 1893.[2] He determined the hydrolysis of the alkali salts of phenol, carbonic acid, boric acid, &c. In this case it is not free acid that we have to determine, but free alkali, and the matter is complicated by the fact that the free alkali is removed from the system as the reaction proceeds, so that the equilibrium of the hydrolysis, as, for instance, $KCN + HOH \rightleftarrows KOH + HCN$, is continually changing. It would lead us too far to go into the details of how this is taken into account. It is

[1] *Zeitschr. für phys. Chem.*, 4, 319 (1889). [2] *Ibid.*, 12, 167 (1893).

sufficient to say that a formula can be deduced for the reaction, and that Shields found it confirmed by experiment.

In spite of the complicated nature of the reaction, very good results can be obtained by this method. The saponification proceeds very much more quickly under the influence of hydroxyl ions than of hydrogen ions, and so the measurement of even very small degrees of hydrolysis can be carried out at the ordinary temperature, which is not the case in the method mentioned previously. Shields was able to measure even such a small degree of hydrolysis as that of sodium acetate—rather less than 0·01 per cent. in $\frac{1}{10}$ normal solution. This is a degree of precision which greatly surpasses that of any determinations of free acid by the catalysis of esters or of cane sugar.

Shields showed that the velocity of saponification was not disturbed by the presence of ester and alcohol. He further showed by this method that trisodium phosphate, Na_3PO_4, is quantitatively split up in aqueous solution into Na_2HPO_4 and $NaOH$.

According to Ley,[1] the saponification of esters sometimes takes place even under the influence of neutral salts, such at KCl at 100°. It is doubtful whether this points to a slight hydrolysis of the salts at this temperature, which seems very improbable, or whether in certain cases other ions besides hydrogen and hydroxyl can act as catalysers in saponifying esters. In any case the velocity of the reaction is very small as compared with that brought about by salts which are known to be hydrolysed.

The following tables give the percentage of hydrolysis of a number of salts of weak acids and bases as determined by this method by Walker and others. For the sake of comparison the values have all been recalculated, so that the figures give the hydrolysis in $\frac{1}{10}$ normal solution.

I.—*Hydrolysis of the hydrochlorides of weak bases as measured by the catalysis of esters.*

Temperature = 25°.

Name of base.	Percentage hydrolysis of Hydrochloride in $\frac{N}{10}$ solution.	Name of base.	Percentage hydrolysis of Hydrochloride in $\frac{N}{10}$ solution.
Thiazol	17	Acetoxime	36
Glycocoll	19	Urea	90
Asparagine	25	Acetamide	98
Thiohydantoïn	30	Propionitrile	99
Asparaginic Acid	31	Thiourea	99

II.—*Hydrolysis of the alkali salts of weak acids as measured by the saponification of esters.*

Temperature = 25°.

Name of Acid.	Percentage Hydrolysis of salts in $\frac{N}{10}$ solution.	Name of Acid.	Percentage Hydrolysis of salts in $\frac{N}{10}$ solution.
Hydrocyanic acid	1·12	*o*-Chlorphenol	1·18
Acetic acid	0·008	2 : 4 . Dichlorphenol	0·29
Carbonic acid	3·17	2 : 4 : 6 Trichlorphenol	0·21
Phenol	3·05	*p*-Cyanphenol	0·29
p-Chlorphenol	1·62	*p*-Nitrophenol	0·16

[1] *Zeitschr. für phys. Chem.*, **30**. 230 (1899).

Inversion of Cane Sugar.—It is well known that the inversion of cane sugar is brought about by the addition of acid to its aqueous solution, and that the reaction can be followed by means of the polarimeter. The velocity of the inversion is proportional to the amount of acid added, and it is evident that this is a method which can be applied to the estimation of the acid which is hydrolytically set free from the salts of weak bases.

The first application of this method appears to have been made by Bruner in 1893. He measured the hydrolysis of a number of inorganic chlorides, nitrates, and sulphates at 40°. His work was, however, very much overlooked, through having been only published in a Polish journal. In 1900 he republished it in the 'Zeitschrift für phys. Chem.' (**32**, 133).

Meanwhile Walker and Aston [1] had determined the hydrolysis of a number of hydrochlorides of weak organic bases, and a few inorganic nitrates by the same method at 60°. Ley extended this work on inorganic salts at 100°.[2] It is impossible to directly compare these results with one another, as they were all obtained at different temperatures. The temperature has been shown to have a very great influence on the hydrolysis, as the dissociation constant of pure water rises abnormally rapidly with rise of temperature.

The inversion is a monomolecular reaction, and the calculations are very similar to those of the catalysis of esters. Ley points out that this method is somewhat limited in its applicability. Some salts which react acid to litmus act as neutral towards cane sugar, and conversely some neutral salts bring about inversion of the sugar. Even potassium chloride brought about inversion of the sugar at 100°, but gave very irregular results. A disadvantage of working at such a high temperature is that the results may be vitiated by impurities dissolved from the glass, and it is probable that something of this sort occurred in the determinations on potassium chloride, &c., for Ley found similar irregularities on making experiments with extremely dilute solutions of hydrochloric acid. The inversion seems also to be considerably influenced by dissolved salts. Ley considered the limit of accuracy to be about 0·5 per cent. in $\frac{1}{100}$ normal solution.

The following tables contain a number of results obtained by the abovementioned observers for the hydrolysis of organic and inorganic chlorides:—

III.—*Hydrolysis of the hydrochlorides of organic bases as determined by the inversion of cane sugar.*

Temperature = 60°.

Name of base.	Percentage Hydrolysis of Hydrochloride in $\frac{N}{10}$ solution.	Name of base.	Percentage Hydrolysis of Hydrochloride in $\frac{N}{10}$ solution.
Pyridine	1·2	Glycocoll	18
Monomethylaniline	1·2	Asparagine	21
Quinoline	1·2	Acetamide	78
p-Toluidine	1·7	Urea	81
Aniline	2·6	Thiourea	92
o-Toluidine	3·2	Propionitrile	92

[1] *J.C.S.*, **67**, 576 (1895).
[2] *Zeitschr. für phys. Chem.*, **30**, 216 (1899).

IV.—*Hydrolysis of inorganic chlorides (inversion method).*

Metal.	Temperature.	Hydrolysis of Chloride in $\frac{N}{10}$ solution.
Zinc	100°	0·1
Lead	,,	0·2
Beryllium	,,	1·8
Aluminium	,,	6·1
,,	77°	2·7
Cerium	100°	0·3
Lanthanum	,,	0·1
Iron (Fe''')	40°	10
Uranyl (UO_2'')	,,	3

The chlorides of the alkali metals and of the alkaline earths, as also those of yttrium, scandium, manganese, cobalt, and erbium, showed no appreciable hydrolysis.

A method somewhat similar to the inversion method was recently suggested by Wood.[1] He allowed diastase to act on starch in presence of a hydrolysed salt. Acids or alkalies retard the action of the diastase, and the retardation was taken as a basis of measurement of the amount of acid or alkali present. The action is very much affected by changes of temperature. So far only rough approximations have been obtained in this way.

Electric Conductivity.—The electric conductivity has for a long time been looked on as a useful method for the determination of hydrolytic dissociation. Its capabilities in this direction have, in my opinion, been considerably overestimated. The method used for the determination is as follows:—It is well known that almost all salts are fairly completely ionised when dissolved in water at a moderate dilution. Their electric conductivities, which form a measure of their ionisations, do not differ from one another by a great deal in solutions of equivalent concentration.

The free acids and bases, on the other hand, have all possible conductivities, ranging from almost nothing in the case of the very weak acids and bases to values very much greater than those of the salts in the case of the strong acids.

If, then, we take the solution of a salt such as aniline hydrochloride, which is considerably split up into free aniline and hydrochloric acid in aqueous solution, the observed conductivity will be partly due to the salt $C_6H_5NH_2HCl$, and partly to the free HCl which is split off by hydrolysis. The free aniline which is present in the system will not contribute appreciably towards the conductivity.

Since the conductivity of hydrochloric acid is very much greater than that of aniline hydrochloride, we shall be able to draw some conclusion from the conductivity as to the amount of free hydrochloric acid which is present in the system. If μ_1 be the molecular conductivity which aniline hydrochloride would have if it were not hydrolysed, μ_{HCl} be that of hydrochloric acid, and x the fraction of the salt which is hydrolysed, the observed molecular conductivity (M) will be

$$M=(1-x)\mu_1, \text{ due to unsplit salt,}$$
$$+ \quad x\mu_{HCl}, \text{ due to free HCl.}$$

[1] *Amer. Chem. Journ.*, **16**, 313.

From this we get

$$x=\frac{M-\mu_1}{\mu_{HCl}-\mu_1}$$

From this the degree of hydrolysis can be calculated.

The conductivity of the hydrolysed salt M can be directly measured with a certain amount of accuracy. The experimental error will amount to perhaps 0·5 per cent. under favourable circumstances, rising to 1 per cent. or more at the highest dilutions (about $\frac{1}{1000}$ normal).

Similarly μ_{HCl} can be ascertained by direct measurement.

The problem is, therefore, to ascertain what the molecular conductivity would be if the salt were not hydrolysed, that is, μ_1. There are several ways of arriving at this, but none permitting of any great accuracy. Walker was the first to attempt to measure hydrolytic dissociation in this way.[1] He determined the electric conductivities of the chlorides and sulphates of a number of very weak organic bases, including salts which were hydrolysed to the extent of nearly 100 per cent.

He arrived at the approximate conductivity which the salts would have in the unhydrolysed state by analogy with similar salts which were known not to be much hydrolysed, and assumed that the molecular conductivities would be equal at the same dilution. As the degrees of hydrolysis were in all cases very large, this served his purpose tolerably well. For instance, for thiazolhydrochloride in $\frac{1}{32}$ normal solution he found M=189·8. He assumed the real value μ_1 to be 90. μ_{HCl} was known to be 375.

$$\text{Hence } x=\frac{189{\cdot}8-90}{375-90}=0{\cdot}35,$$

i.e., the salt is hydrolysed to the extent of 35 per cent. From the catalysis of methylacetate he found 34·6 per cent. The values that he found in this way corresponded pretty closely with those obtained by catalytic methods.

This method of analogy gives, however, only a very rough approximation of the conductivity of the unsplit salt. It was probably several units out in most cases, and for this reason the method is not adapted to the determination of small degrees of hydrolysis. Errors of several per cent. are unavoidable. In the case of the less hydrolysed salts no results could be obtained at all. Indeed, in the case of aniline hydrochloride he found the conductivity to be considerably *smaller* than that calculated from the velocities of migration of the ions which it contains. It is therefore evident that some more satisfactory method is necessary for the determination of the true conductivity (μ_1) of the salt in absence of hydrolysis, if small percentages of hydrolysis are to be measured.

Bredig[2] extended Walker's work in this direction. He determined the true conductivities of such salts as aniline hydrochloride by a very simple device. He added aniline to the solution, and in this way drove back the hydrolysis to such an extent that he could arrive at the true conductivity of the salt. In this way he determined the hydrolysis of aniline hydrochloride and a number of its derivatives.

The converse method of reducing the hydrolysis to a minimum by

[1] *Zeitschr. für phys. Chem.*, **4**, 333 (1889).
[2] *Ibid.* **13**, 321 (1894).

excess of *acid* has deen tried, but, so far, without much success. The method is probably capable of much better development.

The commonest method for the determination of this value μ_1 is a somewhat indirect one. It is a well-known fact that almost all salts are fairly completely ionised in aqueous solution. Thus the molecular conductivity is not very far removed from its limiting value, even at moderately high concentrations, and hence does not rise very much when we increase the dilution. It has been found empirically that the amount by which the molecular conductivity of binary electrolytes increases between any two given dilutions is nearly constant. The conductivity is generally measured at dilutions ranging from 32 litres to 1024 litres. It has been found that in the case of binary electrolytes which are not hydrolysed the molecular conductivity at these two dilutions differs by approximately 10 units at 25°.

$$\mu_{1024}-\mu_{32}=10.$$

Thus the sodium salts of the fatty acids, being scarcely at all hydrolysed, give differences which all approximate to 10 units. The sodium salts of dibasic acids give a difference of about 20 units and so on. In general, the difference, Δ, is given by

$$\Delta=\mu_{1024}-\mu_{32}=10n_1n_2.$$

where n_1 and n_2 are the valencies of the two ions. With hydrolysed salts we get a very different state of affairs. Here we find the differences to be abnormally large, for the following reason. At the highest concentrations the hydrolysis will not come into play very much, and the values found will approximate more or less to the true values. As we increase the dilution, however, the hydrolysis increases more and more, and at the highest dilution a considerable part of the conductivity found will be due to free acid or base, and this will, therefore, as we have seen, be greater than the true conductivity of the salt. Hence the difference Δ will be greater than 10 units.

If, therefore, we find that the difference Δ is abnormally great, the excess may be attributed to hydrolysis, and the extent of the hydrolysis may be calculated by making use of the equation mentioned above :

$$M=(1-x)\mu_1+x\mu_{HCl}.$$

The method cannot be said to be very satisfactory unless the extent of the hydrolysis is very large. First, the measurement of the electric conductivity at a dilution of 1024 litres does not permit of an accuracy of within about 1 per cent. ; and secondly, this value Δ is by no means so constant even for salts which are not hydrolysed as might be desired. It frequently shows deviations of 2 or 3 units, and so a hydrolysis of even 1 per cent. or so might pass unnoticed. We saw that the hydrolysis of sodium acetate could be fairly accurately measured by the velocity of saponification of ethyl acetate. In $\frac{1}{10}$ normal solution it amounts to 0·008 per cent. If we calculate what difference this would make to the conductivity, we find that the abnormality of the Δ value should be about 0·15 unit. It will be at once seen that anything approaching this accuracy is out of the question by the electric method. Indeed, if we compare the values actually found for sodium acetate by two such eminent

investigators as Ostwald and Bredig, we find that Ostwald gives $\mu_{1024} - \mu_{32} = 10{\cdot}1$, whereas Bredig gives $\mu_{1024} - \mu_{32} = 12{\cdot}9$.

When the hydrolysis is greater, however, an approximate idea of it can be gained in this way from the conductivity.

V.—Hydrolysis of the hydrochlorides of organic bases as determined from their electric conductivity.

Temperature = 25°.

Name of base.	Hydrolysis of Hydrochloride in $\frac{N}{10}$ solution.
Aniline	1·5
o-Toluidine	1·8
m-Toluidine	1·3
p-Toluidine	0·9
Betaïn	32·5

VI.—Hydrolysis of inorganic salts (conductivity method).

Temperature = 25°.

Salt.	Hydrolysis in $\frac{N}{10}$ solution.
$AlCl_3$	0·5
$BeSO_4$	0·5
$PbCl_2$	0·4
$UO_2(NO_3)_2$	0·6
$Hg(ClO_4)_2$	6·3

Much more might be added on the subject of electric conductivity as applied to the determination of hydrolysis. Salts in which both the acid and base are weak present quite a different aspect, but a discussion as to their behaviour would lead us too far.

To return to the other methods of estimation, a recent method should be mentioned which differs from those depending on catalysis. We have seen that when a salt such as aniline hydrochloride undergoes hydrolysis two products result, the hydrochloric acid, strongly ionised and active, and the aniline, practically unionised and inactive. All the methods that have been mentioned so far have depended on the measurement of the strongly ionised component, either by its conductivity or by some catalytic action which it brings about.

Under some conditions these determinations become difficult to carry out owing to the decomposition or precipitation of one of the reaction products or from other causes. In these cases it is better to measure the indifferent component. The method that suggests itself most readily is that of extraction with some solvent which is insoluble in water. The laws of distribution of a substance between two solvents are well known, and by making use of these the hydrolysis can be easily calculated from the amount of substance which is extracted. The method was tested recently by Farmer[1] in the following way. The salt is dissolved in a known quantity of water and a known quantity of benzene added. The whole is brought to constant temperature and shaken. The amount of substance extracted by the benzene is then estimated, preferably

[1] *J.C.S.*, **79**, 863 (1901).

volumetrically, and from this the hydrolysis can be easily calculated if the distribution coefficient for the substance in question has been previously determined.

The values found at different dilutions agreed very closely with those required by Arrhenius' 'dilution formula.' So far the method has not been applied much, but it seems to offer advantages over previous methods in several respects. Particularly for solutions which decompose on standing, it seems almost the only available method. It remains to be seen whether this method is capable of the same sensitiveness as that of Shields. If so, it would have the advantage of greater simplicity and rapidity.

The foregoing are, then, the chief methods which have been used up to the present for the determination of hydrolysis.

It will be evident from the abovementioned theory of hydrolytic dissociation that the extent of the hydrolysis depends on the strength of the weak acid or base present in the salts. The relation between the strength of the acid or base and the hydrolysis of its salts can be expressed by a simple mathematical formula.

The dissociation constant is, of course, determined by the electric conductivity. It is only recently, however, that the electric conductivity of such weak acids has been determined with sufficient accuracy to confirm the validity of this formula This was the work of Walker and Cormack.[1] The hydrolysis of the alkali salts calculated from the dissociation constants which they found for phenol and other weak acids agreed very closely with that experimentally found by the saponification method. This forms perhaps the most convincing proof of the soundness of Arrhenius' views as opposed to such theories as the one mentioned earlier, in which the acidity was attributed to the formation of hydrates.

In this way, therefore, it would be possible to calculate the strengths of acids and bases whose electric conductivity is immeasurably small by determining the hydrolysis of their salts.

This, of course, rests on the assumption that no intramolecular rearrangement takes place when salts are formed, which is not always the case. In the case of various dye stuffs, for instance, where the salt formation is accompanied by a change of constitution, we should find that the relation between the strength of the acid and the hydrolysis of its salts did not hold. If the measurements are experimentally possible, such intramolecular rearrangements may be detected in this way. This is a method which has been applied by Hantzsch to prove differences of constitution between certain acids and the salts that they form.

In several cases he found that although the acids were very weak indeed, and should therefore give strongly hydrolysed sodium salts, yet the sodium salts showed only a slight hydrolysis. In the case of dinitroethane, for instance, he found that both the free dinitroethane and its sodium salt reacted neutral, and from this he concluded that the salt formation was accompanied by a change of constitution from $CH_3.CH(NO_2)_2$ to

$$CH_3 . C\begin{matrix}\diagup NO_2 \\ \diagdown NOOH\end{matrix} \quad \text{forming the salt } CH_3 . C\begin{matrix}\diagup NO_2 \\ \diagdown NOONa\end{matrix}$$

Fields of research like this offer inducements for the more accurate determination of hydrolysis on the one hand and of the affinity constants of very weak acids on the other.

[1] *J.C.S.*, 77, 5 (1900).

It has been long recognised that the study of hydrolysis affords the best means of estimating the strengths of very weak acids and bases. Since the affinity constant of pure water is now known with considerable certainty, exact measurements can be made in this way, even when the free acids or bases are difficultly soluble in water. It would, for instance, be possible to make exact determinations of the effect of substituents on the strength of phenol and aniline. The influence of constitution on the affinity constants of these very weak electrolytes would form an interesting field for research.

The Relative Progress of the Coal-tar Industry in England and Germany during the past Fifteen Years. By ARTHUR G. GREEN, *F.I.C., F.C.S.*

[Ordered by the Council to be printed *in extenso*.]

THE coal-tar colour manufacture has well been called the flower of the chemical industries. Although in absolute money value of its products not equalling some other branches of industrial chemistry, it represents the highest development of applied chemical research and chemical engineering, and may well be taken as the pulse of the whole chemical trade. Indeed a country which allows the most scientific branch of chemical industry to languish cannot expect to maintain pre-eminence for long in any simpler branch of chemical manufacture; since the skill trained for attacking the difficult problems of organic chemistry is certain sooner or later to be brought to bear on the simpler questions presented in the manufacture of so-called 'heavy' chemicals (acids, alkalies, bleach, salts, &c.), and processes hitherto often left to the supervision of foremen will be taken in hand by educated chemists, with consequent improvement in methods of manufacture, better yields, purer products, and cheaper production. The importance of the coal-tar industry cannot therefore be estimated alone by the value of its products, for it exerts a widespread effect upon all other branches of chemical manufacture, from many of which it draws its supplies of raw material. As a pregnant example of this influence, especially noticeable during the last decade, I may mention the revolution which is taking place in the manufacture of sulphuric acid, that most important product of the 'heavy' chemical trade. A strong demand had arisen in the colour industry for a large and cheap supply of sulphuric anhydride, chiefly in connection with the manufacture of alizarine colours and of artificial indigo. With the object of satisfying their own requirements in this respect, the Badische Aniline and Soda Works of Ludwigshafen devoted much time and research to the problem of improving the catalytic process usually known by the name of Winckler, a modification of which process had been worked in this country by Squire Chapman and Messel since 1876. This endeavour was attended with such success that by means of the process and plant which they finally evolved they were enabled to produce sulphuric anhydride so cheaply that not only could it be used as such for a large variety of purposes, but by combination with water afforded a profitable source of sulphuric acid. This new method of manufacturing sulphuric acid is, for concentrated acid at least, cheaper than the chamber process; and since the product is absolutely free from arsenic, and can be produced at any desired concentration, it seems likely to supplant eventually the time-honoured method of manufacture.

Besides exerting this influence upon the inorganic chemical manufactures, the coal-tar industry has given birth during recent years to several important daughter industries. The manufacture of synthetic medicinal agents, artificial perfumes, sweetening materials, antitoxines, nutritives, and photographic developers are all outgrowths of the coal-tar industry, and in great part still remain attached to the colour works where they originated. Of these subsidiary industries the most important is the manufacture of synthetic medicinal preparations, which has already attained to large proportions, and bids fair to revolutionise medical science. The requirements of the coal-tar industry have further led to great advances in the design and production of chemical plant, such as filter-presses, autoclaves, fractionating columns, vacuum pumps and stills, suction filters, enamelled iron, aluminium, and stoneware vessels, &c., for the supply of which extensive works have become necessary.

It is a frequently quoted remark of the late Lord Beaconsfield that the chemical trade of a country is a barometer of its prosperity, and the chemical trade of this country has always been regarded as a most important branch of our manufactures. Even those who might be inclined to regard our declining position in the colour industry with more or less indifference would consider the loss of a material portion of our general chemical trade as nothing less than a national calamity. As already pointed out, however, the two are indissolubly connected, the coal-tar industry being an essential and inseparable part of the chemical industry as a whole. It is with the object of ascertaining our present and future prospects in the chemical trade of the world that I propose to compare the relative development of the colour industry in England and Germany during the past fifteen years. It was at the commencement of this period, that is to say in the year 1886, that Professor Meldola, in a paper read before the Society of Arts, gave such a masterly account of the position of the industry of this country at that date, and sounded a warning note to our manufacturers and business men regarding its future progress.

If an excuse is required for my venturing to refer again to a subject upon which so much has been said and written already, it is supplied by the fact that the warnings repeatedly given by those who saw the future clearly (notably by Professor Meldola and Professor Armstrong) have remained largely unheeded by our business men. The conclusions which are forced upon us are unfortunately not of a reassuring nature for our national trade, but it is well to remember that nothing is gained by burying our heads in the sand, and that the cure of a disease can only be effected after an accurate diagnosis of its cause.

The period which we have to consider has been one of extraordinary activity and remarkable development in the coal-tar industry, and before I pass to the economic aspect of the question I shall ask you to consider very superficially some of the main points in this advance. In no other industry than this have such extraordinarily rapid changes and gigantic developments taken place in so short a period, developments in which the scientific elucidation of abstract problems has gone hand in hand with inventive capacity, manufacturing skill, and commercial enterprise. In no other industry has the close and intimate interrelation of science and practice been more clearly demonstrated.

Born in 1858 the colour industry had already attained to a considerable state of development by the year 1886. The period prior to this might well be called the 'rosaniline period,' since it is chiefly marked by

the discovery and development of colouring matters of the rosaniline or triphenylmethane group, such as Magenta, Aniline Blue, Hofmann Violet, Methyl Violet, Acid Magenta, Acid Violets, Phosphine, Victoria Blues, Auramine, Malachite Green, and Acid Greens. Individual members of other groups had already been discovered, but the latter had not yet attained to the importance which they were destined later to occupy. This is especially the case with the class of colouring matters containing the double nitrogen radical known as 'azo' colours. This group of compounds has, during the fifteen years which we have to consider, attained to such enormous dimensions and importance that this interval may fairly be termed the 'azo period.' The number of individual compounds belonging to this class, which have either been prepared or are at present preparable, runs into many millions and far exceeds the members of all other groups of colouring matters put together. In commercial importance also they occupy a position at present far in advance of any other group, the employment of some of them (*e.g.*, the 'azo' blacks) amounting to many thousands of tons annually. A great stimulus to the investigation of the azo compounds was given by the discovery by Böttiger in 1884 of the first colour possessing a direct affinity for cotton (Congo Red), which was followed within a few years by a rapidly increasing series of colours of all shades having similar dyeing properties. The azo colours known prior to this time were either basic colours (Aniline Yellow, Chrysoidine, Bismarck Brown, &c.) or acid wool colours (Xylidine Scarlet, Croceine Scarlet, &c.). The great simplification of cotton dyeing brought about by the introduction of the new group of azo colours—'Benzo' or 'Diamine' colours as they were called—led to a rapid increase of their number, and compounds containing two, three, four, or more double-nitrogen groups, linking together the residues of various paradiamines (benzidine, tolidine, dianisidine, azoxytoluidine, paraphenylenediamine, naphthylenediamine, &c.) to various naphthol-, amidonaphthol-, and naphthylamine sulphonic acids made their appearance in quick succession. Simultaneously therewith proceeded the discovery and investigation of the various isomeric derivatives of naphthalene required as raw products for the preparation of these colours, an investigation which was largely aided by the classical research on the isomerism of naphthalene compounds carried out in this country by Armstrong and Wynne.

Another method of applying azo colours to cotton, by which much faster shades are obtained, was introduced by Messrs. Read Holliday, of Huddersfield, in 1880, and consisted in producing unsulphonated azo compounds on the fibre by direct combination. Owing to the technical difficulties which were at first encountered in applying this process it has only reached its full development during the last few years and at other hands than those of its discoverers. The most important colour produced by this method is Paranitraniline Red, for which over two hundred tons of chemically pure paranitraniline are manufactured annually.

The search for direct cotton colours led the author in 1887 to the discovery of Primuline. This compound, having a direct affinity for cotton and containing at the same time a diazotisable amido group, could be used for the synthesis of various azo colours on the fibre which were remarkable for great fastness to washing. It has had a large employment for the production of fast reds, and the new principle of dyeing which it introduced has been considerably extended in other so-called 'diazo'

colours. The closer investigation of the thiazol group, to which primuline belongs, further led to the discovery of many other cotton colours belonging to this family, amongst the most important of which are the brilliant greenish-yellow called 'Turmerine' or 'Clayton Yellow,' the light-fast 'Chlorophenine' or 'Chloramine Yellow,' the pure greenish basic yellow 'Thioflavine,' and the fast cotton pink 'Erica.'

Passing over the stilbene azo colours and the basic azo ammonium or 'Janus' colours there remains a class of azo compounds to which I must shortly refer, namely, the mordant azo colours, which with the growing demand for faster shades have recently come into much prominence. In these compounds the presence of an ortho hydroxyl or carboxyl group gives to the colour the property (following Liebermann and v. Kostanecki's rule) of combining with metallic mordants, especially chromium oxide, and producing therewith insoluble and fast lakes on the wool or cotton fibre.

We now come to the consideration of three analogously constituted groups of colouring matters, namely, the azines, oxazines, and thiazines. The laborious scientific investigations of Fischer and Hepp, Bernthsen, Kehrmann, and others on the constitution of these groups of compounds, the first members of which (Methylene Blue, Saffranine, and Meldola's Blue) were discovered in a very early stage of the industry when little or nothing was known of their structure, combined with the theoretical views on the quinonoid structure of such colouring matters promulgated by Armstrong and adopted by Nietzki, led to the discovery of many valuable new members of these classes. Amongst the latter may be specially mentioned the Rosindulines, Indoine Blue, Induline Scarlet, Rhodulines, &c.

Passing to the pyrone and acridine groups in which much investigation has also been conducted, the most notable advances have been the discovery of the 'Rhodamines,' a class of pure basic reds, and of the basic yellows and oranges allied to Phosphine, namely Acridine Yellow, Benzoflavine, and Acridine Orange.

It is in the alizarine group next to the azo group that the greatest progress must be recorded. The demand for fast colours for calico printing and for dyeing chrome-mordanted wool to withstand severe 'milling' operations has led to a long series of investigations and patents for producing new derivatives of anthraquinone. These new products, known in commerce as 'Alizarine Bordeaux,' 'Alizarine Cyanines,' 'Anthracene Blues,' 'Alizarine Viridine,' 'Alizarine Saphirol,' &c., are polyoxy- or amidooxy-anthraquinones, for the preparation of which either alizarine or nitroanthraquinones are the usual starting points.

Passing over some smaller groups, we now come to a very peculiar class of dyestuffs containing sulphur, which, although discovered by Croissant and Brettonière in 1873, remained confined to a single representative—'Cachou de Laval'—until Raymond Vidal in 1893 obtained a very fast black colouring matter, which dyed unmordanted cotton, by heating paraamidophenol with sulphur and sodium sulphide. The possibility of replacing Aniline Black in cotton dyeing by a direct colouring matter, and possibly also of obtaining other shades which, though dyed in a single bath, would resist subsequent 'cross dyeing' of the wool in mixed fabrics, lent an immense impulse to the study of this class of colouring matters; and although their molecular structure still remains wrapped in obscurity, many new representatives have followed each

other in rapid succession, ranging in shade from blacks of various hues to browns, olives, greens, and blues. As the most important of these I may mention Vidal Black, Immedial Black, Katechine Black, Immedial Blues, Pyrogene Blues, Katechine Brown, Katechine Green, &c.

It may fairly be claimed, however, that the greatest triumph of the coal-tar industry for the past fifteen years has been the successful production of artificial indigo on a large manufacturing scale.

Returning from the scientific to the economic aspect of the subject, I shall ask you now to consider what share we have obtained in the great expansion of trade resulting from all these new discoveries, many of which have originated in this country. The development of the industry in Germany is well illustrated by the following figures :—

Exports from Germany to the World.

—	1885.	1895.	1899.
	Tons.	Tons.	Tons.
Aniline Oil and Salt	1,713	7,135	—
Coal-tar Colours (excl. alizarine) . .	4,646	15,789	17,639
Alizarine Colours	4,284	8,927	—

Again, if we take values, we find that total exports of coal-tar colours from Germany amounted in 1894 to 2,600,000*l.*, and in 1898 to 3,500,000*l.*, an increase of nearly a million in four years. The latter figure is practically the same as that given by Perkin as an estimate of the *world's* total *production* in 1885, showing how great the increase has been since this date.

The value of Germany's *entire* production is somewhat difficult to arrive at. Witt, in his report on the German chemical exhibit at the Paris Exhibition, gives as the value of the total chemical industry of Germany for the year 1897 the enormous sum of 46½ million pounds sterling. Of this sum Lefevre estimates that at least one tenth may be put down to colouring matters, and another tenth to raw, intermediate, and synthetic products from coal tar other than colours, and he thus assigns for the total annual value of the coal-tar industry of Germany the sum of nine to ten million pounds sterling. With the increase in the production of synthetic indigo, it may be taken to-day to considerably exceed this figure.

One may well wonder what becomes of this enormous quantity of coal-tar products. According to the United States consular reports the 3½ million pounds' worth of coal-tar colours exported by Germany in 1898 were consumed as follows :—

The United States took	750,000*l.*	worth.
The United Kingdom took . . .	730,000*l.*	,,
Austria and Hungary ,, ...	350,000*l.*	,,
Italy ,, ...	225,000*l.*	,,
China ,, ...	270,000*l.*	,,

whilst the rest of the world took the remainder.

The great increase in production in Germany is further shown by the growth in the capital and number of workpeople employed. Thus according to a report of the Badische Works, recently issued, the capital

of this company, which was increased in 1889 from 900,000*l.* to 1,050,000*l.*, will be further augmented this year by the issue of 750,000*l.* of debentures. The number of workpeople employed by this company in 1900 was 6,485, as against 4,800 in 1896, an increase of over 33 per cent. in four years. The firm of Leopold Cassella & Co., of Mainkur, near Frankfurt, have increased the number of their workpeople from 545 in 1890 to 1,800 in 1900.

Passing now to England we find that the imports of coal-tar colours into the country are steadily rising, as is shown by the following figures taken from the Board of Trade returns :—

Imports of Coal-tar Dye-stuffs into England during the last Fifteen Years (excluding Indigo).

1886	£509,750	1894	£599,000
1887	542,000	1895	710,000
1888	569,000	1896	739,300
1889	609,200	1897	695,400
1890	594,400	1898	739,000
1891	586,300	1899	708,800
1892	542,200	1900	720,000
1893	504,000		

Contrasted with this the exports of coal-tar colours manufactured in England have fallen from 530,000*l.* in 1890 to 366,500*l.* in 1899. Comparing these figures with the rapidly increasing export trade of Germany, it is seen that whereas formerly the English export trade in artificial colours was about one quarter that of Germany, it does not now amount to a tenth part. It is therefore only too apparent that we have had but little share in the great increase which this industry has experienced during the past fifteen years, and that we have not even been able to supply the expansion in our own requirements. In order to ascertain what proportion of our own needs we at present furnish, I am able to lay before you the following interesting figures, which have been kindly supplied me by the Bradford Dyers' Association and the British Cotton and Wool Dyers' Association, who together form a very large proportion of the entire dyeing trade :—

Colouring Matters used by Bradford Dyers' Association.

English, 10 per cent. ; German, 80 per cent. ; Swiss, 6 per cent. ; French, 4 per cent.

Colouring Matters used by British Cotton and Wool Dyers' Association.

Aniline Colours.—English, 22 per cent. ; foreign, 78 per cent.
Alizarine Colours.—English, 1·65 per cent. ; foreign, 98·35 per cent.

The *English Sewing Cotton Company* have also very kindly supplied me with a detailed analysis of their consumption, from which it appears that out of a total of sixty tons of colouring matters and other dyeing materials derived from coal tar only 9 per cent. were of English manufacture.

The table of statistics, on the next page, of the six largest German firms gives a fair picture of the present dimensions of the industry in that country.

The joint capital of these six firms amounts to at least 2½ millions.

They employ together about 500 chemists, 350 engineers and other technologists, 1,360 business managers, clerks, travellers, &c., and over 18,000 workpeople. Compared with such figures as these the English colour manufacture assumes insignificant proportions. The total capital invested in the coal-tar colour trade in England probably does not exceed 500,000*l.*, the total number of chemists employed cannot be more than thirty or forty, and the number of workmen engaged in the manufacture does not amount to over a thousand.

Position of the Six Largest Colour Works in Germany in Year 1900.

—	Badische Aniline Works	Meister, Lucius, and Brüning	Farbenfabriken Bayer and Co.	Berlin Aniline Co.	Cassella and Co.	Farbwerk Mühlheim, Leonhardt and Co.	Total of six largest firms
Capital	£1,050,000	£833,000	£882,000	£441,000	Private concern	£157,000	About £2,500,000
Number of Chemists	148	120	145	55			About 500
Number of engineers, dyers, and other technologists	75	36	175	31	60	450	About 350
Commercial staff	305	211	500	150	170		About 1,360
Work-people	6,485	3,555	4,200	1,800	1,800		About 18,260
Dividends in 1897	24 per cent.	26 per cent.	18 per cent.	12½ per cent.	Not known	9 per cent.	—
Dividends in 1898	" "	" "	" "	15 "	" "	3 "	—
Dividends in 1899	" "	" "	" "	" "	" "	5 "	—
Dividends in 1900	" "	20 per cent.	" "	?	" "	nil	—

A similar relative proportion is maintained in the number of patents for new colouring matters and other coal-tar products taken by the English and German firms, as is shown by the following table :—

Comparison of Number of Completed English Patents for Coal-tar Products taken during 1886–1900 *by Six Largest English and Six Largest German Firms.*

German Firms		English Firms	
Badische Aniline Works	179	Brooke, Simpson, & Spiller	7
Meister, Lucius, & Brüning	231	Clayton Aniline Co.	21
Farbfabriken Bayer & Co.	306	Levinstein	19
Berlin Aniline Co.	119	Read, Holliday, & Co.	28
L. Cassella & Co.	75	Claus & Reé	9
Farbwerk Mühlheim, Leonhardt & Co.	38	W. G. Thompson	2
Total of six German firms	948	Total of six English firms	86

Nor does the potential loss which we have sustained by our inability to take advantage of a growing industry represent the sum total of our losses. The new colouring matters, made almost exclusively in Germany have in many cases been introduced as substitutes for natural products which were staple articles of English commerce. Madder and cochinea have been replaced by alizarine and azo scarlets, the employment of many

dyewoods has greatly decreased, whilst at the present moment logwood and indigo are seriously threatened. Regarding the indigo question so much has been written that I do not propose to occupy space in its further discussion, but will only point out that the complete capture of the indigo market by the synthetic product, which would mean a loss to our Indian dependencies of 3,000,000*l.* a year, is regarded by the Badische Company as so absolutely certain that, having already invested nearly a million pounds in the enterprise, they are at present issuing 750,000*l.* of new debenture capital to provide funds to extend their plant for this purpose! In the last annual report of the company they say: 'As regards plant indigo, the directors are prepared and determined to meet this competition in all its possible variations in value. Much strange matter has been published in India as to improvements in the cultivation and preparation of natural indigo, but the illusions of the planters and indigo dealers are destined to be dispelled before facts, which, although they are not known to them, will make themselves more felt the larger the production of artificial indigo becomes.'

Besides the loss of material wealth which the neglect of the coal-tar trade has involved to the country, there is yet another aspect of the question which is even of more importance than the commercial one. There can be no question that the growth in Germany of a highly scientific industry of large and far-reaching proportions has had an enormous effect in encouraging and stimulating scientific culture and scientific research in *all* branches of knowledge. It has reacted with beneficial effect upon the universities, and has tended to promote scientific thought throughout the land. By its demonstration of the practical importance of purely theoretical conceptions it has had a far-reaching effect on the intellectual life of the nation. How much such a scientific revival is wanted in our country the social and economic history of the past ten years abundantly testifies.

The position with which we are confronted is in truth a lamentable one, and the way out is not so easy to find. In 1886 it could perhaps still be maintained that we held the key to the situation if we chose to make use of it, inasmuch as the principal raw products of the colour manufacture (tar oils, naphthalene, anthracene, soda, ammonia, iron, &c.) were in great measure imported from England. In a speech to the Academy of Sciences of Munich in 1878 Professor von Baeyer had said: 'Germany, which in comparison with England and France possesses such great disadvantages in reference to natural resources, has succeeded by means of her intellectual activity in wresting from both countries a source of national wealth. Germany has no longer to pay any tribute to foreign nations, but is now receiving such tribute from them, and the primary source from which this wealth originates has its home, not in Germany, but in England. It is one of the most singular phenomena in the domain of industrial chemistry that the chief industrial nation and the most practical people in the world has been beaten in the endeavour to turn to profitable account the coal tar which it possesses. We must not, however, rest upon our oars, for we may be sure that England, which at present looks on quietly while we purchase her tar and convert it into colours, selling them to foreign nations at high prices, will unhesitatingly cut off the source of supply as soon as all technical difficulties have been surmounted by the exertions of German manufacturers.'[1] Professor von

[1] Quoted by Mr. Levinstein, *Jour. Soc. Chem. Ind.*. 1886, p. 350.

Baeyer could not believe that the English manufacturer and capitalist would stand calmly by and see an important industry which had had its origin and early development in his own country taken from beneath his nose without an effort to retain it. Yet the initial advantages which our natural resources afforded us have been neglected, and now in 1901 the conditions are completely changed. The adaptation of condensing plant to the Westphalian coke ovens has rendered Germany, though still a large buyer from England, no longer dependent on English tar and ammonia; by the development of the ammonia-soda process she no longer requires English alkali; whilst all other raw products of the colour industry can now be purchased in the commercial centres of Germany at least as cheaply as in England, and some even at lower prices. Through the shortsightedness, ignorance, and want of enterprise of those with whom the care of the colour industry in this country has rested the opportunity has been allowed to pass for ever. The English capitalist has passed over as not sufficiently profitable for his consideration an industry which at present amounts to nine or ten million sterling annually, and from which his German confrère reaps a dividend of nearly 20 per cent. The English manufacturer has considered that a knowledge of the benzol market was of greater importance than a knowledge of the benzol theory, and after the early but brilliant days in the infancy of the industry when guided by such eminent workers as Hofmann, Perkin, and Nicholson, commercial progress and scientific investigation went hand in hand, but little encouragement has been given here to chemical investigators and discoverers. The control of the industry unfortunately soon passed into the hands of men who had no knowledge and absolutely no appreciation of the science upon which their business rested, and, concerned only with getting the ultimate amount of present profit, discouraged all scientific investigations as waste of time and money. The chemist who devoted himself to the elucidation of the chemical constitution of a colouring matter was regarded by them as an unpractical theorist of no value to a manfacturing business. Even when he discovered new colouring matters of commercial value they were so blind to their own interests, and so incapable of believing that any practical good could come out of such theoretical work, that in many cases they refused to patent or in any way take advantage of the discoveries made by him. During recent years this attitude has certainly undergone considerable modification, and some attempt has been made to call in the aid of the science so long neglected. Certain firms indeed must be given the credit of endeavouring to pursue a more enlightened policy, but these attempts have been of a more or less sporadic nature and always directed too much in the expectation of realising immediate financial results. The difficulties which must be encountered in the attempt to regain the lost ground are of necessity very great, and are quite unappreciated by our business men. It seems in fact to have been the opinion of the public and the average financial man that this industry ought to be easily won back by us by the establishment of a few technical schools, the engagement of a dozen chemists, and the investment of a few thousand pounds in new plant, forgetting that the supremacy of our German competitors has been gained by years of patient toil, by the work of hundreds of trained chemists, and by the outlay of millions of capital. Who can be surprised therefore if such expectations have not been realised, and if in spite of some notable successes the general position of the colour trade

in England at the present day, at a time when even the German trade is suffering from the general depression, looks worse than at any previous period? During years of stagnation in this country the German manufacturers have been realising large profits, which they have employed in consolidating their businesses, writing off the value of their buildings and plant, and accumulating enormous reserves (the reserve of the Badische Company is over a million pounds): they have gathered round them perfectly working organisations, comprising enormous staffs of scientifically and practically trained research chemists, factory chemists with highly specialised knowledge, chemical engineers, dyers, and others; their travellers and agents are in every part of the globe; by long manufacturing experience and unremitting endeavour to improve their processes and plant they have brought the yields and quality of their products to such a state of perfection that even when the manufacture of these products is no longer covered by patents they are able to produce them at a cost price which is impossible to anyone commencing their manufacture; they have hedged themselves about with a perfect stockade of many hundreds of patents, have accumulated in their laboratories thousands of intermediate products ready at any time to be subjected to any new treatment or combination which research or theory may suggest as likely to yield new results. By the complete range of colours which they are able to offer in each group of dyestuffs, whether basic colours, acid colours for wool, fast colours dyeing on metallic mordants, diazotisable colours, or direct colours for cotton, and by the invaluable aid and assistance which they can give the dyer in his daily work, they are enabled to retain his custom even if it sometimes happens that a better and a cheaper article is offered him by the home producer.

Where, then, are we to look for an improvement? Some would find a remedy in the imposition of heavy protective tariffs; but such tariffs in France have not availed to prevent a similar state of things there, and protection in colouring matters might have a very detrimental effect upon the textile industries of the country. Others expect salvation from the extension of technical schools; but laudable as is the aim of these institutions, I cannot see how they can effect much until their raw material is of a very different character from what it is at present, and until the public can be completely disabused of the fallacy that a year or two of technical training pumped into an ignorant schoolboy will produce a better works chemist than a university course of scientific study laid upon the foundation of a good general education. Mr. Levinstein again bases his hopes for the future upon a reform of the patent laws, and seeks to compel all patented processes to be worked in this country. Although I am inclined to believe that a portion of our present troubles have been brought about by a bad patent law, framed mainly from an engineering and not from a chemical point of view, which seems specially designed to foster foreign trade at our own expense, yet I cannot attribute to this cause a too preponderating influence, and am doubtful whether its removal now would materially improve the position. The remedy for the present state of affairs must of necessity be a slow one, and in my opinion can only be found in a better appreciation of the value of science throughout the length and breadth of the land. Until our Government and public men can be brought to realise the importance of fostering the study of science and of encouraging all scientific industries, until our schools and universities appreciate the importance of a scientific education, until the rewards

for public services in science are made equal to those in other branches of the public service, so long will science continue to be held in insufficient esteem in our country, and the best and most promising of our rising young men will be deterred from adopting chemistry as a profession. It is not so much the education of our chemists which is at fault as the scientific education of the public as a whole.

The Application of the Equilibrium Law to the Separation of Crystals from Complex Solutions and to the Formation of Oceanic Salt Deposits. By Dr. E. FRANKLAND ARMSTRONG.

[Ordered by the Council to be printed *in extenso*.]

THE celebrated deposits of Stassfurt consist, it is well known, of an immense thickness of Rock salt, interspersed at fairly regular intervals with narrow bands of anhydrous Calcium sulphate capped with beds rich in Magnesium and Potassium salts. That such salt deposits are of marine origin is obvious; but as their amount is much greater than could have been derived from the evaporation of the body of water present on the area over which they are distributed, even supposing its depth to have been that of the very deepest oceans yet known, a constant flowing in of water containing salts during the period of evaporation must be assumed to have taken place. As will be obvious later on, the presence of alternate bands of Anhydrite and Rock salt throughout the deposits affords further proof that such an inflow must regularly have taken place.

Roughly, the deposits may be divided into the following four regions:

1. Anhydrite ($CaSO_4$).
2. Polyhalite ($2CaSO_4.MgSO_4.K_2SO_4.2H_2O$), about 60 metres thick.
3. Kieserite ($MgSO_4.H_2O$), about 30 metres.
4. Carnallite ($MgCl_2.KCl.6H_2O$), about 23 metres.

The presence in these deposits of salts such as Anhydrite and Kieserite, which are not those normally deposited from simple aqueous solutions, is in itself proof that the character of the separation is affected by the conditions—*i.e.* the presence of other salts. The problem has been to determine the exact conditions which would give rise to such deposits. But the consideration of the separation of the salts from sea-water is merely a special and somewhat complex case of the more general problem involved in the study of the separation of crystalline deposits from solution, whether in the ordinary solvents familiar to the chemist or in solvents such as are fused metals and silicates.

The work hitherto done in this field has been conducted entirely by van't Hoff and his pupils, and has already been carried so far that it is possible almost completely to interpret the geological phenomena afforded by the Stassfurt deposits.

The results fall under what is commonly termed the Phase rule of Willard Gibbs. No difficulty can arise in understanding them when graphic methods are used.

It is before all things essential to bear in mind, in the first place, that a solution can only be spoken of as *saturated* with a given substance when the substance is present in the solid state in contact with the solution. Thus, for equilibrium to exist in the case of Sodium sulphate it is necessary to have the salt in solution together with the undissolved substance. The phase rule is but an expression of the fact that, in the case of solutions in

volatile solvents, equilibrium—*i.e.* saturation—is attained at a particular pressure at a particular temperature, and *vice versâ*, when n substances are present in $n+1$ states or phases separable as such, each such state being termed technically a phase.[1] It is necessary to make this distinction in order to guard against the application of the term 'phase' to the radicles of salts. The whole investigation may therefore be considered independently of the modern hypothesis of solution, solely on the basis of facts.

The real difficulty that occurs in practice is to know what are the possible phases—in other words, to determine the nature of the double salts or distinct hydrates that may be formed. In the case of saturated solutions of non-volatile solids in a volatile solvent, as vapour of the solvent is always present, the solvent occurs in two phases, and therefore the condition under which equilibrium—*i.e.* saturation—is determined is that $n-1$ solids exist in contact with the liquid. As the presence of these solids determines the equilibrium, they may very properly be spoken of as *equilibrators*, and this term may be used as the equivalent of the somewhat inexpressive German phrase '*Bodenkörper*.'

The cases to be considered are the following :—

CASE I.—*Solutions saturated with a single salt.*

In these two constituents (salt and water) are present in three phases—the gaseous phase, one liquid phase, and one solid phase—and as a rule only one solid equilibrator can act at a time ; but as not only the anhydrous substance, but also its various hydrates, may equally serve as equilibrators when hydrates are formed, two equilibrators—either the anhydrous substance and its hydrate, or two of its hydrates if there be more than one possible—may act simultaneously at some particular pressure and temperature, usually called the *transition point*. Obviously this complication arises from a variation in the behaviour of the substance relatively to the solvent as the external conditions are modified. As hydrates only differ in the number of solvent molecules they contain, they are to be regarded as but one substance, the molecules of the solvent attached to them being left out of account. In any case, the presence in the solid state as equilibrator of the particular compound or compounds with which the solution is to be saturated is always the essential factor.

To give an example : in the case of Sodium sulphate, the monohydrate and decahydrate coexist in equilibrium with the solution at 32°·65 under the corresponding vapour pressure ; but it follows from the above that at any other temperature only one at a time of the hydrates can be in equilibrium with the solution, inasmuch as a single substance cannot, as a rule, give rise to a solution saturated with reference to two such equilibrators, the existence of two such compounds, except at the transition point, being only possible in presence of a second salt : this serving, in fact, to condition the change in hydration.

CASE II.—*Solutions saturated with two salts which possess similar basic or acid radicles, e.g.*, NaCl, KCl.

[1] It must, however, be noted that if there be either n or fewer phases present, equilibrium is possible under every set of conditions compatible with the existence of the phases considered. For example, in the case of an unsaturated solution of Sodium chloride in presence of its vapour, no solid phase being present, the vapour pressure of the solution at each temperature is different at different concentrations : and therefore a solution and its vapour may be in equilibrium at any pressure within the possible limits at each particular temperature.

In these three constituents are present in four phases, and two solid equilibrators are necessary, *e.g.*, NaCl and KCl. But it must be carefully borne in mind that when a double salt can be formed there are two possible cases of equilibrium—viz., that in which the double salt and one of the single salts and that in which the double salt and the other single salt are in contact with the liquid.

Similarly, when one of the salts gives rise to two or more hydrates, there are several possible cases of equilibrium, though in this case also the presence of but two equilibrators at a time is possible, as a rule. Moreover, two hydrates of the same substance may act simultaneously as equilibrators, even under conditions other than those obtaining at the transition points, as another substance is present. A case of this kind is afforded by the formation of solutions saturated with the two hydrates of Magnesium sulphate in presence of Magnesium chloride.

CASE III.—*Solutions saturated with two salts, whose basic and acidic radicles are different and which therefore can interact.*

Magnesium sulphate and Potassium chloride may be quoted in illustration of this case. In solution these interact in the manner expressed by the equation

$$K_2Cl_2 + MgSO_4 \rightleftarrows K_2SO_4 + MgCl_2,$$

one or other couple being stable, according to the conditions; such pairs of salts are therefore conveniently spoken of as *reciprocal salt pairs.*

A solution of two such salts may be supposed to consist of *four* substances—the solvent and *three* of the four possible salts—in five phases and not of five substances in six phases as the rule would seem to require. The fourth salt being always obtainable from the other three, from the standpoint of the phase rule the four salts are derivable from only three substances: thus the stable pair at a certain temperature being, let us say, $K_2Cl_2 + MgSO_4$, these will exist together with *either* K_2SO_4 or $MgCl_2$, but not with both, as the two cannot be together without interacting to form the stable pair.

Although in the case of a reciprocal salt pair only three equilibrators are essential to secure saturation, and this is the maximum number that can act simultaneously, except at a transition point, the number of combinations of three which are possible may be considerable. In the case of KCl and $MgSO_4$, which can give rise not only to K_2SO_4 and $MgCl_2$, but also to various double salts and hydrates, experience indicates that (at temperatures about 25°) in all seven substances may be formed—viz., KCl, K_2SO_4, $MgCl_2.6H_2O$, $MgSO_4.7H_2O$, $MgSO_4.6H_2O$, Schönite ($K_2SO_4.MgSO_4.6H_2O$) and Carnallite ($MgCl_2.KCl.6H_2O$). As each of these should serve as an equilibrator, and there are mathematically thirty-five ways of combining three out of seven substances, the problem at first seems very complicated. In practice, however, it is found that, for example, K_2SO_4 and $MgSO_4$ cannot exist together, but always form the double salt Schönite; and that in a similar manner $MgCl_2$ and KCl give rise to Carnallite, so that finally the number of possible sets of three equilibrators is reduced by experiment to five. In the case of a mixture of KNO_3, $NaNO_3$, KCl, and NaCl, as neither double salts nor hydrates are formed, the conditions are simplified, and only four sets of three equilibrators can be chosen. In practice the determination of the number of forms stable under the conditions of experiment often gives rise to considerable difficulty; and it must not be forgotten that the problem can only be solved

experimentally, the phase rule itself giving no assistance in this part of the inquiry: in fact, the only purpose it serves is to limit the number of the equilibrators.

CASE IV.—All cases in which other salts are added to a reciprocal salt pair resolve themselves into the general case of x substances occurring in $x+1$ phases, and therefore requiring $x-1$ equilibrators. The number of substances which can act as equilibrators may be very large, and of course can only be ascertained by experiment: when their number is determined the various ways of associating them, taken $x-1$ at a time, are readily deduced. Experiment is then again required to eliminate those which are incompatible. In special cases a simplification may be introduced by taking one or more salts as always present among the equilibrators. Thus, in the case of sea water, Sodium chloride and Calcium sulphate are always taken as two of the equilibrators.

Experimental Methods.

The data required in drawing diagrams to represent the composition of saturated solutions and the order in which salts are deposited from them are arrived at by means of determinations of solubility. As a knowledge of the character of the substances which can exist separately is essential, a preliminary investigation must often be carried out to determine the conditions under which given double salts or hydrates are stable, or the synthesis of such compounds may have to be effected for the first time. A variety of methods are made use of in this part of the inquiry, the determination of volume-change by means of the dilatometer, and of vapour-pressure by means of the tensimeter, being of special importance in establishing transition points.

The precautions to be observed in determining solubilities are often insufficiently appreciated. The exact method followed in van't Hoff's laboratory may therefore be described.

The determinations have hitherto been made at 25°, this temperature being both easy to reach in the laboratory and to maintain constant, whilst probably not so very far removed from that which may have prevailed at the time the Stassfurt deposits were laid down.

A large water-bath is used as thermo-regulator, its temperature being kept constant by means of a modified Ostwald Calcium chloride regulator, whilst for smaller baths a regulator on the same principle filled with toluene is used. It is essential to use weighed quantities of everything, so that the approximate composition of the solution may be ascertained by calculation at any moment.

The determinations are made in a large test tube, about 3 cm. broad and 30 cm. long, immersed as deeply as possible in the bath. The contents are kept in violent agitation by means of a screw-shaped glass stirrer passing though a piece of glass tubing inserted in the tightly fitting stopper of the test tube: this stirrer is actuated by a small motor. If the tube be selected so that the rod of the stirrer just fits it, and a little grease be inserted, no loss of water by evaporation is to be feared.

The solubility determinations are carried out by stirring weighed quantities of the substances with a known quantity of water, an excess of solid being always used. When approximately saturated, the solution is characterised in some way, *e.g.*, by ascertaining its density. In determining

the solubility of mixtures, each of the equilibrators is then added and the liquid stirred during twenty-four hours, when the density is again determined. To ascertain whether the necessary equilibrators are all present some of the solid is microscopically examined ; and to leave no room for doubt a few c.c. of the solution are left in contact with a clear crystal of each equilibrator in a test tube at 25° during twenty-four hours to see if this remain unaltered. The solution having been analysed is then again stirred during a further period, more of each equilibrator being added, and the tests and analyses are repeated ; if the results agree, the solution is regarded as saturated. For minor details, often of considerable importance, the original publications must be consulted. The best test of saturation is to maintain the solution in contact with a sharply defined crystal of an equilibrator : should this remain unaltered, the solution is in equilibrium with it. It may seem that the precautions described are exaggerated, but experience shows that this is not the case, a curious lag in the formation of a compound being often met with which prevents the attainment of equilibrium—indeed, this is one of the chief difficulties in such inquiries.

The Graphic Expression of the Results.

CASE I.—As a typical simple case, a solution containing the chlorides of Sodium and Potassium may be taken ; these salts neither give rise to double salts, nor are they capable of existing in various hydrate forms. On evaporating at a constant temperature a solution containing, say, equal molecular quantities of the two chlorides, the solution will first become saturated with the less soluble—viz., KCl—and this will separate as the solution becomes concentrated. Subsequently the solution becomes saturated with Sodium chloride as well as with Potassium chloride ; from this point onwards, two solid equilibrators being present, further concentration will cause the separation of both salts in constant proportions and the solution will gradually evaporate without altering in composition. To construct the diagram, therefore, three determinations are necessary—viz., the composition of the solutions saturated with (*a*) NaCl, (*b*) KCl, (*c*) both NaCl and KCl.

It is convenient to express the solubility as the proportion which the number of molecules of dissolved salt bears to 1000 molecules of water.

If the solubilities of the pure substances are plotted on rectangular co-ordinates, that of the one as influenced by the other will be represented by a point inside the rectangle. In the following diagram the line AC represents the change in the amount of Sodium chloride in the saturated solution as the amount of Potassium chloride increases, whilst BC gives the change in the amount of Potassium chloride in the saturated solution as the amount of Sodium chloride increases. This diagram therefore expresses the composition of all possible solutions containing both Sodium and Potassium chlorides at 25° ; obviously :

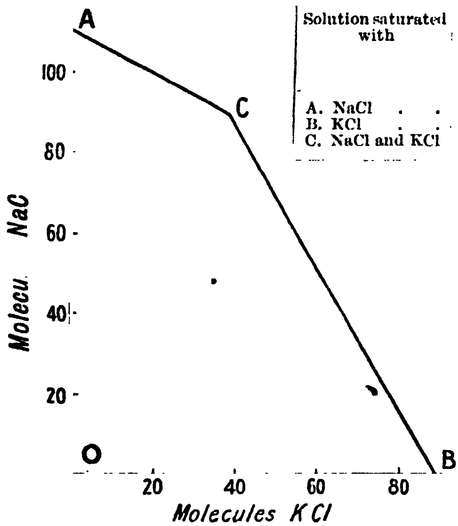
(1) All solutions falling on the line ACB are saturated with the one or the other salt, and with both at the point C, whilst (2) unsaturated solutions are represented by the region inside the figure OACB and (3) supersaturated solutions by the region outside ACB.

It is important to bear in mind that, as the diagram shows, on proceeding from the origin O towards any point on the line ACB, the solution remains unsaturated until that line is reached. At points

between B and C Potassium chloride alone separates; at points between A and C Sodium chloride alone. The point C is that at which alone the two salts mutually saturate the solution, and at which, on further evaporation, they separate together in constant proportions.

CASE II.—Whereas in the above case the two salts were considered to be incapable of acting on each other, in general the formation of a double salt is possible. It is to be borne in mind, however, that the double salt is not to be regarded as a distinct substance, and an additional equilibrator is therefore not required. As an example, KCl and $MgCl_2.6H_2O$ may be taken, which give rise to Carnallite, a double salt of great importance in natural deposits. In such a case a stable system is formed when only the one or the other of the two simple salts coexists with the double salt, except at the transition point; at all other points, when either is present in excess, it acts on the other, forming a fresh quantity

FIG. 1.

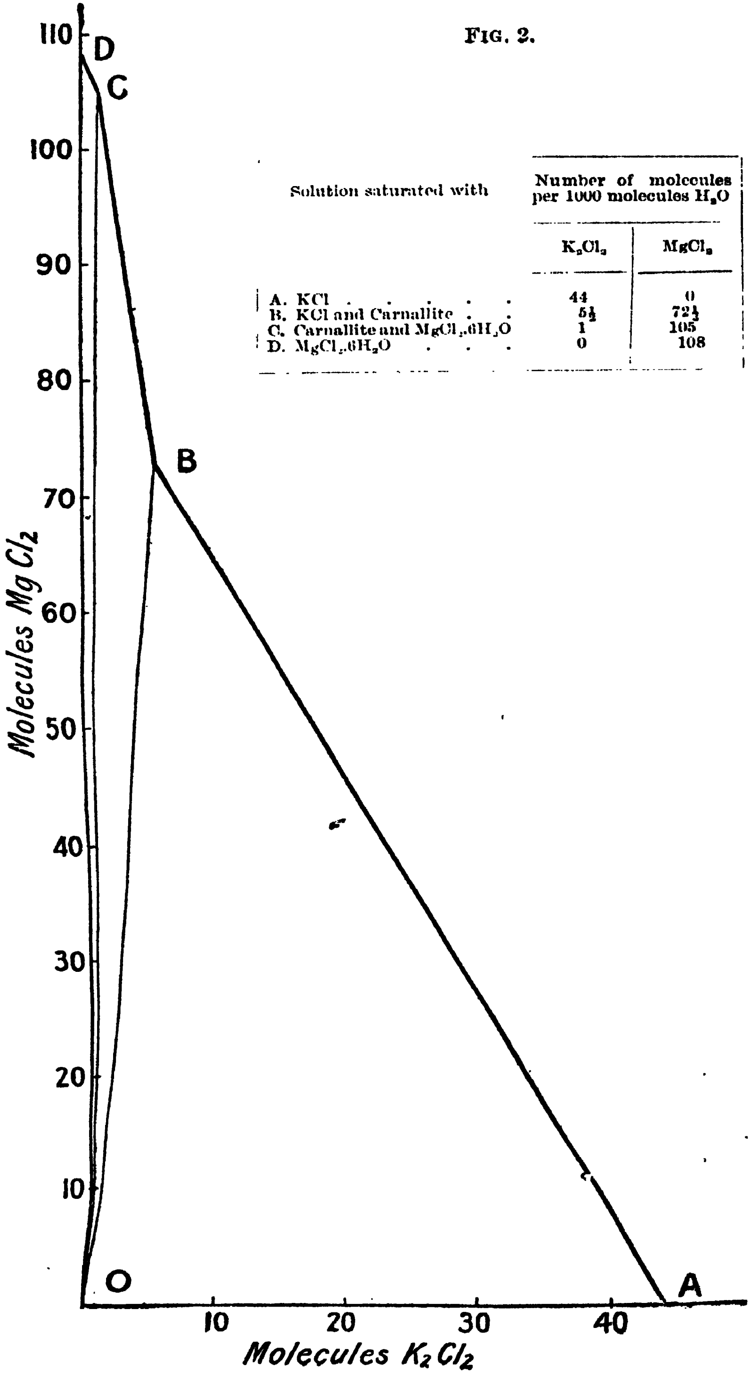


Solution saturated with	Number of molecules per 1000 molecules H_2O: NaCl	KCl
A. NaCl	111	0
B. KCl	0	88
C. NaCl and KCl	89	39

of double salt. The four determinations of solubility to be made in the case in question are (1) that of KCl, (2) that of $MgCl_2.6H_2O$, (3) that of Carnallite and KCl, (4) that of Carnallite and $MgCl_2.6H_2O$.

On plotting the values as before, the diagram on page 268 is obtained (fig. 2). In this the line AB represents the manner in which the amount of Potassium chloride present in the saturated solution changes as the amount of Magnesium chloride is increased. At the point B the solution is saturated with Potassium chloride and Carnallite. In the region OBC Potassium chloride is no longer present as such, but only as Carnallite, and the slope BC represents the gradual depletion of the solutions saturated with Carnallite as the amount of Magnesium chloride in solution increases. At the point C the solution is saturated with Carnallite and Magnesium chloride, the line DC showing the decrease in the amount of Magnesium chloride in the saturated solution as the amount of Potassium chloride present increases. Only Magnesium chloride and

FIG. 2.



Solution saturated with	Number of molecules per 1000 molecules H_2O	
	K_2Cl_2	$MgCl_2$
A. KCl	44	0
B. KCl and Carnallite . .	5½	72½
C. Carnallite and $MgCl_2.6H_2O$	1	105
D. $MgCl_2.6H_2O$	0	108

Carnallite are present in the region ODC. The difference between the regions OBC and ODC consists in the fact that in the former Carnallite, and in the latter Magnesium chloride, predominates, one or other of these salts, as the case may be, separating when the solution is concentrated. In both cases the composition of the solution tends towards that represented by the point C. When this point is reached Magnesium chloride and Carnallite are deposited together in constant proportions, the solution evaporating to dryness without further change of composition. It will hence be obvious that the point C is one of critical importance, as defining the conditions under which the final crystallisation takes place. It is termed by German workers the '*Krystallisations Endpunkt*'—the terminus of crystallisation. The determination of such points is the object in view in discussing a problem such as that afforded by the Stassfurt deposits.

It is, however, necessary to make one more stipulation in order to render the previous statements universally true—viz., that the regular sequence of crystallisation may not be followed unless the product which separates is periodically removed from contact with the solution. If this be not done, secondary action may take place, and the product at first formed may be eaten up again by the solution. For example, if after reaching the point B the deposited Potassium chloride be not removed, on further concentration, as two equilibrators are present, the solution will evaporate without changing its composition ; but as a large excess of Magnesium chloride is present, and this gradually comes into operation as water is removed, Potassium chloride will be continually re-dissolved (42·5 mols. K_2Cl_2 per 100 mols. Carnallite deposited). As soon as all solid Potassium chloride is removed, the deposition of Carnallite causes the composition of the solution to change until the 'end-point' C is reached. In interpreting such diagrams, therefore, it is to be assumed that the products deposited are removed from solution at the proper moment. It may be supposed that this often takes place in nature through the deposition of a protecting layer of mud.

CASE III.—*Reciprocal salt pairs.* As an example may be taken the reciprocal salt pair which is of greatest importance in the investigation of sea water—*i.e.*, that represented by the equation

$$MgCl_2 + K_2SO_4 \rightleftarrows K_2Cl_2 + MgSO_4.$$

These salts give rise to two double salts, and at least two hydrates of $MgSO_4$ have to be considered ; therefore it is necessary to determine the composition of the saturated solutions of the stable combinations of seven substances, taken

(*a*) Singly,
(*b*) In pairs,
(*c*) Three at a time.

The table on page 270 shows the composition of the various solutions fulfilling the conditions of equilibrium.

Considering the table in detail, in the case of solutions saturated with a single salt it is only necessary to point out that the Potassium chloride is expressed in double molecules, as a system of equivalent notation must be used. The meaning of the figures appended to the solutions saturated with two salts is in most cases at once apparent, but the solution H requires a few words of explanation, as the equilibrators in this case

are not the only necessary constituents. The simultaneous existence of the two hydrates of Magnesium sulphate, as already pointed out, is only possible when the solution contains, in addition, a certain proportion of Magnesium chloride—viz., 73 molecules, the determination of which is the outcome of tentative trials.

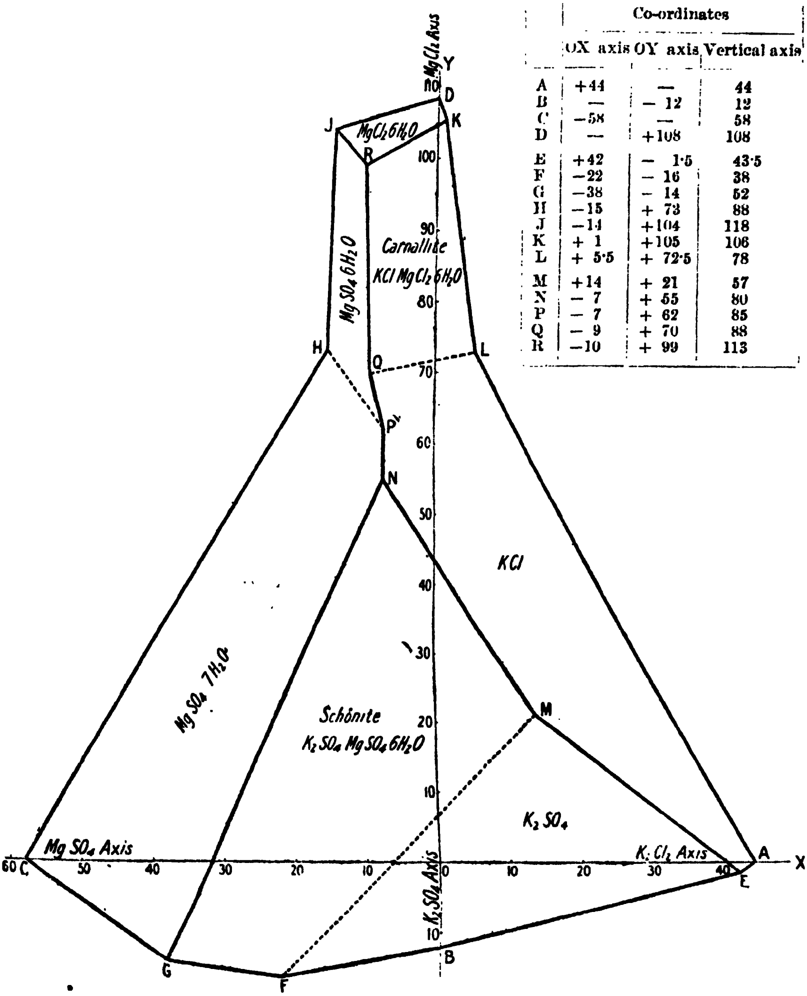
At 25° 1000 molecules H_2O dissolve	Molecules				Total no. of mols.
	K_2Cl_2	K_2SO_4	$MgSO_4$	$MgCl_2$	
1. Solutions saturated with a single salt:					
A. KCl	44	—	—	—	44
B. K_2SO_4	—	12	—	—	12
C. $MgSO_4.7H_2O$	—	—	58	—	58
D. $MgCl_2.6H_2O$	—	—	—	108	108
2. Solutions saturated with two salts:					
E. KCl, K_2SO_4	42	$1\frac{1}{2}$	—	—	$43\frac{1}{2}$
F. K_2SO_4, $K_2Mg(SO_4)_2.6H_2O$	—	16	22	—	38
G. $K_2Mg(SO_4)_2.6H_2O$, $MgSO_4.7H_2O$	—	14	38	—	52
H. $MgSO_4.7H_2O$, $MgSO_4.6H_2O$	—	—	15	73	88
J. $MgSO_4.6H_2O$, $MgCl_2.6H_2O$	—	—	14	104	118
K. $MgCl_2.6H_2O$, $MgKCl_3.6H_2O$	1	—	—	105	106
L. $MgKCl_3.6H_2O$, KCl	$5\frac{1}{2}$	—	—	$72\frac{1}{2}$	78
3. Solutions saturated with three salts:					
M. KCl, K_2SO_4, $K_2Mg(SO_4)_2.6H_2O$	25	—	11	21	57
N. KCl, $K_2Mg(SO_4)_2.6H_2O$, $MgSO_4.7H_2O$	9	—	16	55	80
P. KCl, $MgSO_4.7H_2O$, $MgSO_4.6H_2O$	8	—	15	62	85
Q. KCl, $MgSO_4.6H_2O$, $MgKCl_3.6H_2O$	$4\frac{1}{2}$	—	$13\frac{1}{2}$	70	88
R. $MgSO_4.6H_2O$, $MgKCl_3.6H_2O$, $MgCl_2.6H_2O$	2	—	12	99	113

Turning to solutions saturated in presence of three equilibrators, a difficulty arises in expressing the composition of the solution, as chemical analysis only gives a measure of the amount of the various radicles present, and affords no information whatever as to the nature of the salts present and their relative amounts—*i.e.*, apart from hypothesis nothing is known as to the state in which salts exist in solution. As in practice the solution is saturated in presence of three known salts, its constitution is most rationally represented by expressing the analytical results as much as possible in terms of these. However, bearing in mind the equation for a reciprocal salt pair, and the fact that the constitution of a solution is expressed in molecular proportions, a little consideration shows that it is of minor importance how the composition of the solution is expressed, the important fact being that, when saturated in presence of three known substances, it has a definite chemical composition. The table printed above shows the composition of the sixteen saturated solutions which can be made by using one or more of the equilibrators derivable from the reciprocal salt pair. Geometrically, there are many possible ways of graphically representing such a set of results—that chosen by van't Hoff practically involves plotting the four salts on axes at right angles to each other in such a manner that reciprocal salts are measured in opposite directions on the same axis. In such a diagram (fig. 3) the solutions saturated with a single salt are represented by points on the axes, all other saturated solutions giving points between the axes. Thus, the points A, B, C, and D fall on the four axes, whilst a point E representing the solution saturated

in presence of KCl and K_2SO_4 is plotted 42 units along the K_2Cl_2 axis (to the right) and 1·5 unit along the K_2SO_4 axis (downwards).

Turning to the point M ($1000H_2O + 25K_2Cl_2 + 11MgSO_4 + 21MgCl_2$), and similar points representing solutions saturated in presence of three equilibrators, and bearing in mind the fact that the composition of the

FIG. 3.



	Co-ordinates		
	OX axis	OY axis	Vertical axis
A	+44	—	44
B	—	− 12	12
C	−58	—	58
D	—	+108	108
E	+42	− 1·5	43·5
F	−22	− 16	38
G	−38	− 14	52
H	−15	+ 73	88
J	−14	+104	118
K	+ 1	+105	106
L	+ 5·5	+ 72·5	78
M	+14	+ 21	57
N	− 7	+ 55	80
P	− 7	+ 62	85
Q	− 9	+ 70	88
R	−10	+ 99	113

solution cannot be expressed in terms of less than three salts, it is obvious that a correct geometric representation can only be obtained by the use of three co-ordinates. The method chosen has been to plot the reciprocal salt pairs on axes at right angles in a plane, and the total number of molecules in solution on a third axis vertically upwards from this plane. The surfaces passing through points in space thus obtained represent areas within

which the solutions are saturated with a given substance. By joining the points in the horizontal plane, areas are obtained which represent in plan the surfaces in space just referred to.

To plot the horizontal plan some thought is necessary, as there are three salts to be represented on two axes and therefore one of the salts must be eliminated. In the case under consideration, in which Magnesium chloride and Potassium sulphate are the reciprocal salts on the one axis, to plot Magnesium chloride, Potassium sulphate must be eliminated. This is already done in the case in question in calculating out the results given in the table on p. 270; therefore it suffices to measure off twenty-one $MgCl_2$ units upwards from the origin. As Potassium chloride and Magnesium sulphate are the reciprocal salts represented on the second axis, to plot Potassium chloride, Magnesium sulphate must be eliminated, or *vice versâ*. To do this, it is only necessary to bear in mind that

$$25K_2Cl_2+11MgSO_4+21MgCl_2$$
$$=25K_2+(11+21)Mg+11SO_4+(25+21)Cl_2,$$

which, assuming the SO_4 to be present wholly as K_2SO_4, in order to eliminate $MgSO_4$, gives

$$11K_2SO_4+14K_2Cl_2+32MgCl_2.$$

Therefore fourteen units of Potassium chloride are measured off on the K_2Cl_2 axis from the origin. In practice the straightforward geometric method needs only to be followed, and the number of molecules of the one salt, less the number of molecules of its reciprocal, may be measured off on the one axis, the value deduced from the corresponding pair being measured off on the other. The five points M, N, P, Q, and R, when so plotted, fall inside the framework, and to complete the diagram are joined to one another, or to the appropriate points on the framework—*i.e.*, to those representing solutions saturated in presence of two of the three equilibrators present at the particular point inside the diagram. Thus the point M, representing a solution saturated in presence of KCl, K_2SO_4, and Schönite, is joined to the points E, representing a solution saturated in presence of KCl and K_2SO_4, and F, representing a solution saturated in presence of K_2SO_4 and Schönite, but not to either G or L, as these represent solutions saturated in presence of only one of the three equilibrators. The lines divide the diagram into areas or fields, each field representing a solution saturated with but one salt in presence of varying quantities of other salts.

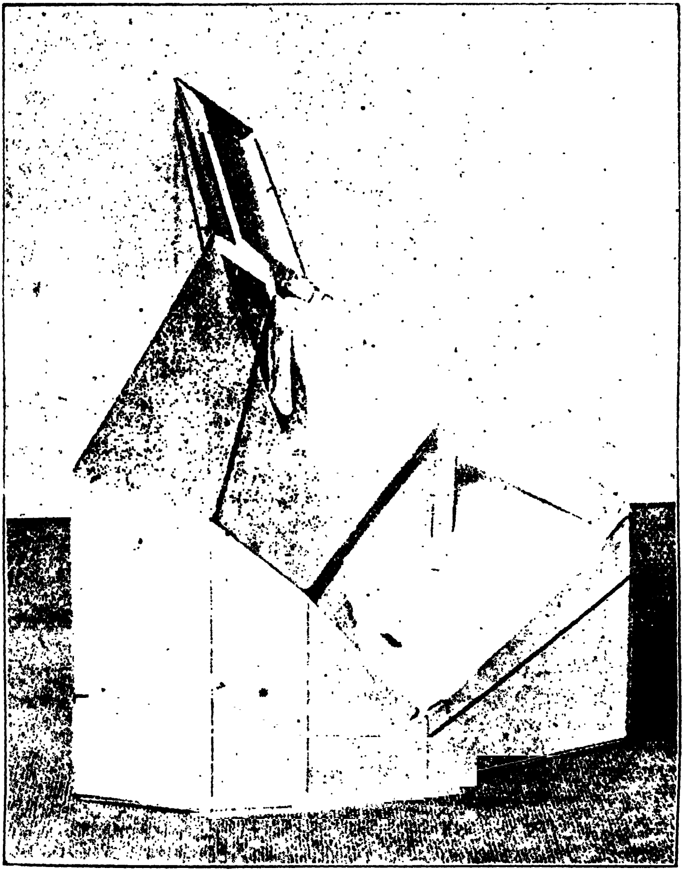
To complete the graphic representation, ordinates are erected at each point of equilibrium representing the total number of molecules in solution. The surfaces touching the extremities of these ordinates represent the various saturated fields.

To complete the model it is necessary to join the origin, O, by triangular surfaces to each of the marginal points, A—L; the hollow surface so formed is the true base of the model. Fig. 4 is reproduced from a photograph of a rough cardboard model so constructed. The model is supported in its true position on the plane diagram by cardboard sheets which represent the vertical co-ordinates at all points on the outer edges of the diagram.

In interpreting the model it is to be noted that points within the solid represent the compositions of all possible solutions. Points within the fields on the upper surfaces represent solutions saturated with one,

whilst points lying on edges other than those at the margin represent solutions saturated with two, and the angular points solutions saturated with three equilibrators. On account, however, of the number of marginal points to each field—in no case fewer than four—the upper surfaces

FIG. 4.



Model of Solutions derived from the Reciprocal Salt Pair $MgCl_2 + K_2SO_4$.

cannot be represented by single planes, and the information at present available is not sufficient to determine their character; they are therefore not introduced into the model.[1]

[1] To construct the model, the lengths of the edges terminating at O are calculated from the co-ordinates of the marginal angular points—each length being $\sqrt{x^2+y^2+z^2}$, where x, y, and z are the co-ordinates of the points considered—whilst the lengths of the other edges are best found by graphical construction. The triangles forming the hollow base are then drawn and cut out in one piece from a sheet of stiff cardboard which is then bent round and fastened in position by a strip of tough paper gummed along the edge. The edges of the upper surfaces are

In working backwards it must be borne in mind that a diagram such as fig. 3 is not alone sufficient to give complete information about a reciprocal salt pair. Only two of the three values required can be deduced from it; to obtain the third, either the model must be used, or a table showing the composition of the various saturated solutions, such as that on page 270, must be referred to.

Thus, assuming the composition of a solution to be that represented at M in diagram, fig. 3, it is obvious that the 'plane' co-ordinate values are $21MgCl_2 + 14K_2Cl_2$. On reference to the model or table it is seen, however, that solution M contains, when saturated, 57 molecules of dissolved salt; therefore the number of other molecules present is $57-(21+14)=22$. But it is to be remembered that these consist of two reciprocal salts, and that in constructing the diagram one member of the pair was equated against the other, so that only half the 22 molecules in solution are to be regarded as present as sulphate—in this case $MgSO_4$—and the remaining 11 molecules are considered to be molecules of K_2Cl_2, and are added to the number of molecules read off from the diagram. The constitution of the solution at M is therefore:

$$21MgCl_2+(14+11)K_2Cl_2+11MgSO_4.$$

Before passing to the consideration of the diagram thus constructed, it is necessary to realise that the points of equilibrium situated on the margin are not all of the same order of stability. In cases in which double salts are formed, the deposition of the double salt necessarily follows, but never attends, that of the less soluble constituent. That this should be the case is obvious when it is borne in mind that, as water is removed, the more soluble constituent—the action of which is more or less impeded by the water—is able to combine with the less soluble to form a further quantity of double salt. The same argument applies to hydrates: as water is removed from the solution the other salts present gradually assert a dehydrating effect.

The points F, H, L on the diagram are cases of this kind, and therefore they are united by dotted instead of by full lines to the appropriate points within the diagram. In indicating the direction in which crystallisation proceeds arrows are therefore drawn through, and not towards, these points.

To illustrate the way in which the diagram is read several cases may be taken.

At B the solution contains only Potassium sulphate. At a point on B E a little to the right of B there is a small amount of chloride present; on evaporating such a solution change proceeds along the line B E, Potassium sulphate alone separating until the point E is reached, when Potassium chloride will also be deposited. The solution will then dry up without changing its composition.

Similarly, starting from a point X a little to the right of B, but a little above B E and within the Potassium sulphate field, the track followed will be along a line B X produced, until E M is reached, which then becomes the track.

It may not be superfluous to add that the track followed from any point X within the diagram is always along a line drawn through X from the point at which the field is saturated with its characteristic salt.

represented by narrow strips of cardboard of the required length; and the vertical ordinates of the angular points M to R are represented by strips of cardboard fixed to the base of the model

On the other hand—and the case is somewhat more complicated—at a point on B F, a little to the left of B, the solution contains a small amount of Magnesium sulphate, the reciprocal of the Potassium chloride considered in the previous case. On evaporating such a solution, change proceeds along the line B F, K_2SO_4 separating as before until the point F is reached. The character of the subsequent change will be determined by the presence or absence of Potassium sulphate: if it be removed, crystallisation proceeds along F G; but if it be left in contact with the solution Schönite is continually deposited, the composition of the liquid remaining unchanged until the whole of the Potassium sulphate originally deposited is redissolved by the excess of the Magnesium sulphate in the solution. Only then will crystallisation proceed along F G, and when G is reached the liquid will dry up without further change in composition.

Starting within the diagram, again in the K_2SO_4 field—say from a point Y, a little to the left of B and a little above B F—the track followed will be along the line B Y produced until F M is reached at a point *fm*. If the Potassium sulphate be then removed, the Schönite field is entered. To determine the course followed across this, it is to be noted that the point at which Schönite alone is present in a saturated solution must be taken as the origin. To deduce this we have to bear in mind that the line GF represents the manner in which the solubility of Schönite varies as the proportions of Magnesium and Potassium sulphates vary; therefore the theoretical solubility of Schönite alone—*i.e.*, when there is no excess of either of the single salts present—is at a point F′ on O F produced equidistant from the two axes on which the separate salts are plotted—*i.e.*, on the line bisecting the angle B O C.

The track followed across the Schönite field will therefore be in the direction F′ *fm* produced. When M N is reached Potassium chloride will separate. It will be obvious that to reach the $MgSO_4.7H_2O$ field it would be necessary to have but little chloride present.

Beyond N Schönite gives way to Magnesium sulphate heptahydrate, which is deposited together with Potassium chloride until P is reached. From P, after removal of the heptahydrate, change would proceed through Q to R. It is obvious that it would not occur along P H, as continued concentration would involve the conversion of the heptahydrate into hexahydrate, and would therefore merely condition a lag in the crystallisation, supposing the heptahydrate were not removed. In like manner change would not proceed along Q L, as concentration would involve a gradual conversion of unremoved Potassium chloride into Carnallite. At R the solution would dry up unchanged in composition.

As a proof of the correctness of this method of interpreting the diagram, the results may be quoted which were obtained by van't Hoff on concentrating a solution of equal molecular quantities of Potassium sulphate and Magnesium chloride, *i.e.*, 174·3 gm. $K_2SO_4 + 223{\cdot}4$ gm $MgCl_2$ $6H_2O$. The use of such a solution is equivalent to starting in the plane diagram from the origin, as the geometric convention followed involves one of the salts being represented as a negative quantity of its reciprocal. As the origin lies within the K_2SO_4 field, the diagram shows that K_2SO_4 will be the first salt to separate, and that concentration will proceed along the Magnesium chloride axis until the Schönite boundary is reached; the separation of Schönite will then set in. Provided the Potassium sulphate be not removed, the course of change will now be along F M to M; when this is reached the deposition of Potassium chloride begins.

In the actual experiment the solution was slowly evaporated at 25°. The deposit was frequently examined with the microscope. At first only Potassium sulphate crystallised out, but subsequently this was mixed with Schönite. As soon as the separation of Potassium chloride was observed to take place the deposited salts were removed and analysed. The amounts found were :—

$$\begin{array}{l} 25 \text{ gms. } K_2SO_4 \\ 120 \text{ gms. } K_2Mg(SO_4)_2.6H_2O. \end{array}$$

The amount of the two salts that should be deposited from such a solution may be calculated as follows :—

At the origin the solution has the composition

$$K_2SO_4+MgCl_2+aH_2O,$$

from which is deposited

$$xK_2SO_4+y.K_2Mg(SO_4)_2.6H_2O,$$

whilst w parts of solution of the composition represented at M remain—*i.e.*,

$$w(1000H_2O+25K_2Cl_2+21MgCl_2+11MgSO_4).$$

Thus

$$\begin{array}{l} K_2SO_4+MgCl_2+aH_2O=xK_2SO_4+yK_2Mg(SO_4)_2.6H_2O \\ \quad +w(1000H_2O+25K_2Cl_2+21MgCl_2+11MgSO_4). \end{array}$$

Collecting and equating the coefficients of the various radicles, the values of x, y, and w are determined.

Thus

$$\begin{array}{ll} Cl_2 \ 1=(25+21)w & \therefore \ w=\frac{1}{46}. \\ Mg \ 1=y+(21+11)w & \\ \qquad 1-\frac{32}{46}=y & \therefore \ y=\frac{7}{23}. \\ K_2 \ 1=x+y+25w & \\ \qquad 1-\frac{7}{23}-\frac{25}{46}=x & \therefore \ x=\frac{7}{46}. \end{array}$$

The K_2SO_4 deposited is thus $\frac{7}{46}$ of the molecule, *i.e.*, $=\frac{7}{46}\times 174{\cdot}3$ $=26{\cdot}5$ gms. ; whilst the Schönite is $\frac{7}{23}$ of the molecule, *i.e.*, $\frac{7}{23}\times 422{\cdot}8$ $=122{\cdot}6$ gms., which values agree closely with those found by experiment.

In following the course of change with the aid of the model, it is noticeable that although, as a rule, concentration proceeds along an upward slope, this is not invariably the case. Thus, whereas on passing from B to F, and from F to G, the slope is upwards, from C to G the slope is downwards; a slight confusion is thereby introduced. It is to be expected that as concentration proceeds the proportion of molecules of dissolved salt to water molecules should steadily increase; and as the vertical ordinates represent the number of dissolved molecules, it would seem that the number of molecules in the saturated solution of Magnesium sulphate is greater than in the solution saturated with Magnesium sulphate and Schönite. If, however, it be assumed that at C a larger proportion of the Magnesium sulphate molecules are present in the form

of complexes $(MgSO_4)_x$, than is the case at G where the solution is saturated with both Magnesium sulphate and Schönite, the discrepancy disappears; and, if the necessary correction could be made and the vertical ordinate at C lowered accordingly, the model would afford a more uniform indication of the direction of change.

Obviously the conditions in solution are complex, especially when several salts are present; and the only phase in which the alteration is of the same character throughout is that which has hitherto been left unnoticed—viz., the vapour phase. As concentration proceeds, and the dissolved salt more and more asserts a mastery over the water molecules, the vapour pressure necessarily diminishes—saturation with each salt corresponding to a particular vapour pressure. From this point of view as the vapour pressure at B (22·2 mm.) and that at C (20·9 mm.) exceeds that at G (20·4 mm.), there is clear evidence that the proportion of dissolved molecules at G exceeds that at C, and that the separation takes place towards G from both B and C. A model may be constructed which affords a clear representation of the order in which the separations occur if the differences between the vapour pressures of the various saturated solutions in presence of their equilibrators and the vapour pressure of water (23·52 mm.) be taken as vertical ordinates. The model thus constructed brings into prominence the fact that the separation of salts from solution always occurs along slopes tending in one direction, and may be regarded as a corrected form of the model previously considered.

The character of this correction is shown in fig. 4 by a thick line drawn round the model at the required height. The highest point in the corrected model is of course the end-point R, and the new vertical scale has therefore been fixed by taking the ordinate of R to represent the maximum vapour pressure difference. The following table gives the necessary data:—

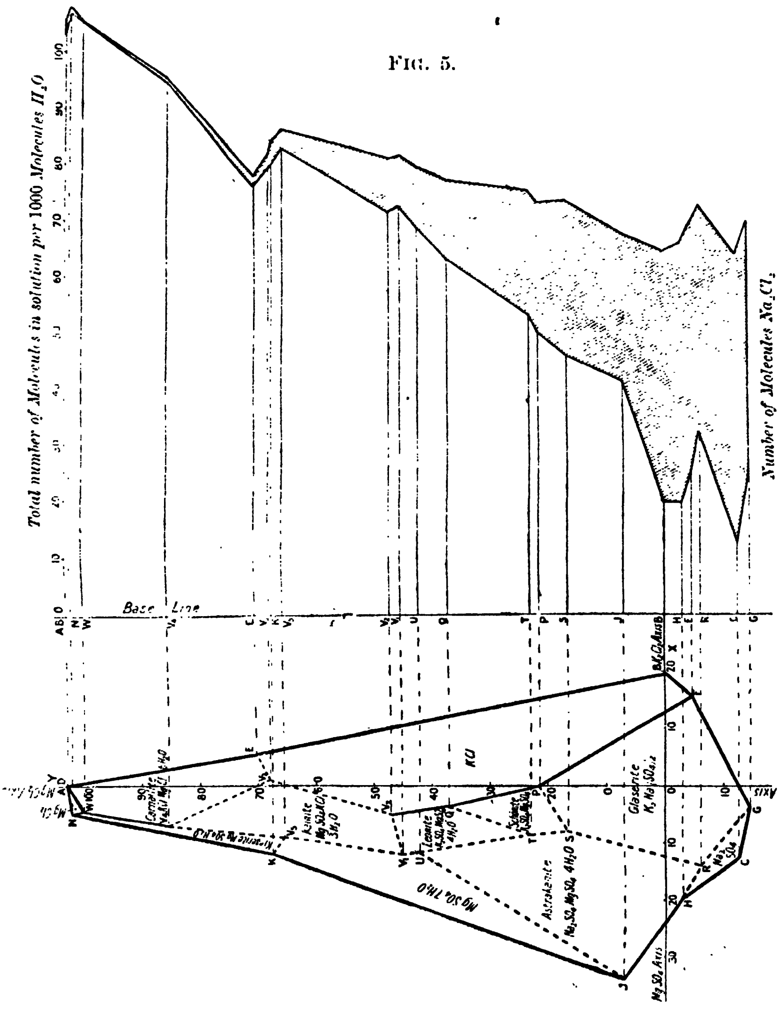
—	Solution saturated with	Vapour Pressure	23·52 – Vapour Pressure
A	KCl	19·2	4·3
B	K_2SO_4	22·2	1·3
C	$MgSO_4.7H_2O$	20·9	2·6
D	$MgCl_2.6H_2O$	7·7	15·8
E	KCl, K_2SO_4	19	4·5
F	$K_2SO_4, K_2Mg(SO_4)_2.6H_2O$	21·6	1·9
G	$K_2Mg(SO_4)_2.6H_2O, MgSO_4.7H_2O$	20·4	3·1
H	$MgSO_4.7H_2O, MgSO_4.6H_2O$	12	11·5
J	$MgSO_4.6H_2O, MgCl_2.6H_2O$	7·5	16·0
K	$MgCl_2.6H_2O, MgKCl_3.6H_2O$	7·6	15·9
L	$MgKCl_3.6H_2O, KCl$	12·7	10·8
M	$KCl, K_2SO_4, K_2Mg(SO_4)_2.6H_2O$	18	5·5
N	$KCl, K_2Mg(SO_4)_2.6H_2O, MgSO_4.7H_2O$	13·7	9·8
P	$KCl, MgSO_4.7H_2O, MgSO_4.6H_2O$	12	11·5
Q	$KCl, MgSO_4.6H_2O, MgKCl_3.6H_2O$	11·9	11·6
R	$MgSO_4.6H_2O, MgKCl_3.6H_2O, MgCl_2.6H_2O$	7·3	16·2

CASE IV.—*A reciprocal salt pair + Sodium chloride.* It is desirable to take this case into account as bearing on the problem of the crystallisation of salts from sea water. In sea water Sodium chloride is present in large excess in comparison with the other salts, and therefore is always in solution with the other salts at every

stage in the process of concentration so long as its presence is compatible with that of the other salts; moreover, it continually separates, and in the natural deposits always accompanies the other salts.

In representing the behaviour of solutions containing, in addition to Sodium chloride, Magnesium sulphate and Potassium chloride—the salts present in the case previously considered—to construct a diagram, as the

FIG. 5.



composition of such a solution cannot be expressed in terms of fewer than four salts, a fourth dimension would need to be introduced were it not that, as Sodium chloride is always present, it may be represented in the form of a sheet of varying thickness spread over the upper surface of the model representing the composition of the various solutions in terms of the other salts present; to construct this sheet the number of molecules

of Na_2Cl_2 are measured off above this surface on the axis drawn from the origin at right angles to the plane of the paper. The shaded area in fig. 5 gives a picture of the thickness of the salt sheet above the various fields in relation to the number of molecules of other salts present in the solutions.

The data required for the construction of a diagram and model representing the behaviour of the solutions under consideration are obtained by determining the composition of solutions saturated (*a*) with Sodium chloride and one other salt; (*b*) with Sodium chloride and two other salts; and (*c*) with Sodium chloride and three other salts. To ensure uniformity, as the results only express the constitution of the solutions in terms of the salt radicles, the convention followed consists in expressing the whole of the Sodium as chloride, and if there be not sufficient Chlorine for this purpose the excess is reckoned as sulphate; the K_2, Mg, Cl_2, SO_4 are expressed as K_2Cl_2, $MgCl_2$, and $MgSO_4$. The experimental data which have been accumulated are given in the following table, which includes the vapour pressures of the various saturated solutions.

—	1000 Molecules Water dissolve Molecules					No. of Molecules excluding Na_2Cl_2	No. of Molecules including Na_2Cl_2	Vapour Pressure	Vapour Pressure. 25°
Saturated with NaCl and	Na_2Cl_2	K_2Cl_2	$MgCl_2$	$MgSO_4$	Na_2SO_4				
A. $MgCl_2.6H_2O$	2½	—	103	—	—	103	105½	7·63	15·89
B. KCl	41½	19½	—			19½	61	16·84	6·68
C. Na_2SO_4	51		—	—	12½	12½	63½	17·5	6·02
D. $MgCl_2.6H_2O$ and Carnallite	1	½	103½	—	—	104	105	7·52	16·00
E. KCl and Carnallite	2	5½	70½	—	—	76	78	12·66	10·86
F. KCl and Glaserite	44	20	—		4½	24½	68½	16·84	6·68
G. Na_2SO_4 and Glaserite	41½	10½	—		11½	24½	69	17·0	6·52
H. Na_2SO_4 and Astrakanite	46		—	16½	3	19½	65½	17·1	6·42
J. $MgSO_4.7H_2O$ and Astrakanite	26	—	7	34	—	41	67	15·1	8·42
K. $MgSO_4.7H_2O$ and $MgSO_4.6H_2O$	4	—	67½	12	—	79½	83½	12	11·52
N. $MgCl_2.6H_2O$, Magnesium sulphate	1	—	102	5	—	107	108	7·55	15·97
P. KCl, Glaserite, Schönite	23	14	21½	14	—	49½	72½	15·9	7·62
Q. KCl, Schönite, Leonite	14	11	37	14½	—	62½	76½	14·9	8·62
R. Na_2SO_4, Glaserite, Astrakanite	40	8	2	14	8	32	72	—	—
S. Glaserite, Astrakanite, Schönite	27½	10½	16½	18½		45½	73	—	—
T. Astrakanite, Schönite, Leonite	22	10½	23	19	—	52½	74½	—	—
U. $MgSO_4.7H_2O$, Astrakanite, Leonite	10½	7½	42	19	—	68½	79	—	—
V_1 Kainite, $MgSO_4.7H_2O$, Leonite	9	7½	45	19½	—	72	81	—	—
V_2 „ KCl, Leonite	9½	9½	47	14½	—	71	80½	—	—
V_3 „ KCl, Carnallite	2½	6	68	5	—	79	81½	—	—
V_4 „ Carnallite, Magnesium sulphate	½	1	85½	8	—	94½	95	—	—
V_5 Kainite, $MgSO_4.7H_2O$, $MgSO_4.6H_2O$	3½	4	65½	13	—	82½	86	—	—
W. Carnallite, $MgCl_2.6H_2O$, Magnesium sulphate	0	½	100	5	—	105½	105½	7·4	16·12
Saturated with NaCl only	—	—	—	—		—	55½	17·7	5·82

In constructing a diagram (fig. 5) and model from these data, as there is no axis on which Sodium sulphate can be directly represented, to express the amount of this salt present in the solutions C, F, G, H, R, a line of argument is adopted similar to that made use of in equating Magnesium sulphate with Potassium chloride, in the case of the reciprocal salt pair previously considered. It is obvious that we may write

$$Na_2SO_4 = MgSO_4 + Na_2Cl_2 - MgCl_2 :$$

in other words, Sodium sulphate can be expressed in terms of three other salts.

—	Co-ordinates		Vertical Axis	
	OX Axis	OY Axis	No. of Molecules excluding Na_2Cl_2	No. of Molecules including Na_2Cl_2
A	—	$+103$	103	$105\frac{1}{2}$
B	$+19\frac{1}{2}$	—	$19\frac{1}{2}$	64
C	$-12\frac{1}{2}$	$-12\frac{1}{2}$	$12\frac{1}{2}$	$63\frac{1}{2}$
D	$+\frac{1}{2}$	$+103$	104	105
E	$+5\frac{1}{2}$	$+70\frac{1}{2}$	76	78
F	$+15\frac{1}{2}$	$-4\frac{1}{2}$	$24\frac{1}{2}$	$68\frac{1}{2}$
G	-4	$-14\frac{1}{2}$	$24\frac{1}{2}$	69
H	$-19\frac{1}{2}$	-3	$19\frac{1}{2}$	$65\frac{1}{2}$
J	-34	$+7$	41	67
K	-12	$+67\frac{1}{2}$	$79\frac{1}{2}$	$83\frac{1}{2}$
N	-5	$+102$	107	108
P	0	$+21\frac{1}{2}$	$49\frac{1}{2}$	$72\frac{1}{2}$
Q	$-3\frac{1}{2}$	$+37$	$62\frac{1}{2}$	$76\frac{1}{2}$
R	-14	-6	32	72
S	-8	$+16\frac{1}{2}$	$45\frac{1}{2}$	73
T	$-8\frac{1}{2}$	$+23$	$52\frac{1}{2}$	$74\frac{1}{2}$
U	$-11\frac{1}{2}$	$+42$	$68\frac{1}{2}$	79
V_1	-12	$+45$	72	81
V_2	-5	$+47$	71	$80\frac{1}{2}$
V_3	$+1$	$+68$	79	$81\frac{1}{2}$
V_4	-7	$+85\frac{1}{2}$	$94\frac{1}{2}$	95
V_5	-9	$+65\frac{1}{2}$	$82\frac{1}{2}$	86
W	$-4\frac{1}{2}$	$+100$	$105\frac{1}{2}$	$105\frac{1}{2}$

Thus, supposing a solution C to contain $12\frac{1}{2}$ molecules of Sodium sulphate, to express its composition, a point in space is plotted by measuring off from the origin $12\frac{1}{2}$ units along the Magnesium sulphate axis and $-12\frac{1}{2}$ units along the Magnesium chloride axis ; *i.e.*, downward and therefore along the Potassium sulphate axis. The point c on the diagram is thus obtained. The corresponding point on the model is deduced by measuring off $12\frac{1}{2}$ on the Sodium chloride axis vertically upwards and adding 51 on account of the 51 molecules of Sodium chloride supposed to be present in the solution as such.

It will be noticed that Magnesium and Potassium sulphates do not appear in the table as single salts which can be used as equilibrators in presence of excess of Sodium chloride, the reason being that new reciprocal salt pairs are constituted by the presence of the Sodium chloride, and interactions take place which destroy these sulphates ; *e.g.*,

$$MgSO_4 + Na_2Cl_2 = Na_2SO_4 + MgCl_2.$$

The remarkable character of the changes brought about by the presence of Sodium chloride will at once be obvious on contrasting figs. 3 and 5. The double salts formed by Magnesium and Potassium sulphates with Sodium sulphate occupy the lower portions of the diagram, Potassium sulphate disappearing altogether, and the area of the Magnesium sulphate field being much restricted. Moreover the greater pull on the water molecules exerted by the soluble Sodium chloride molecules brings about the partial dehydration of several of the compounds appearing in diagram 3 : causing, for example, the displacement of the greater part of the Schönite field by Leonite, $MgK_2(SO_4)_2.4H_2O$, and of the $MgSO_4.6H_2O$ field by Kieserite. In addition, a new double salt, Kainite, $MgSO_4.KCl.3H_2O$, appears.

The order in which separation occurs is at once given by reference to a vapour-pressure diagram constructed, *e.g.*, by inserting the 'vapour-pressure difference' at each of the various transition points.

The Evaporation of Sea Water.

On concentrating sea water—disregarding Calcium sulphate on account of the small quantity present—the first salt to crystallise out is Sodium chloride. When deposition of this salt sets in, the solution has the composition :

$$1{,}000H_2O\ 47Na_2Cl_2\ 1{\cdot}03K_2Cl_2\ 7{\cdot}36MgCl_2\ 3{\cdot}57MgSO_4.$$

Following the rules previously given, it is obvious that the position in space of the point a, which represents a solution of this composition, will be $3{\cdot}57-1{\cdot}03=2{\cdot}54$ units on the OX axis to the left of the origin, 7·36 units above the origin on the OY axis, and $1{\cdot}03+7{\cdot}36+3{\cdot}57=11{\cdot}96$ units above the plane.

As long as only Sodium chloride is deposited, the relative proportions of the Potassium and Magnesium salts remain unchanged, and only the amount of these salts present relatively to the water increases. Such a change is expressed in a model constructed in the manner previously described by motion along a line joining the origin to a, away from O. To ascertain what salt will separate next, the point at which this line ultimately cuts the upper surface of the model must be determined. When this is established with the aid of the model, it is found to lie in the Magnesium sulphate ($MgSO_4.7H_2O$) field. Hence it follows that further concentration ultimately causes the separation of Magnesium sulphate together with Sodium chloride, and the course followed on evaporation will be across the Magnesium sulphate field, away from the hypothetical point representing the solution saturated only with Magnesium sulphate and Sodium chloride. This point must be on the Magnesium sulphate axis as well as on the line KJ (representing the change in composition of a solution saturated with Magnesium sulphate and Sodium chloride as the amount of Magnesium chloride varies), and will obviously fall at their point of intersection, J′. Supposing the Magnesium sulphate field to have been cut at a point β, the path followed on concentrating the solution will be along J′β produced, until the next field is entered. In a similar manner, the subsequent course is traceable until the point W is reached. As a matter of fact, some uncertainty exists as to the exact course of crystallisation, as the investigation of Leonite, Kainite, and Kieserite is not yet complete.

The order in which the salts are deposited is probably as follows :—

(1) NaCl ; (2) NaCl and $MgSO_4.7H_2O$; (3) NaCl and Leonite ; (4) NaCl, Leonite, and KCl, or NaCl and Kainite ; (5) NaCl, Kieserite, and Carnallite ; (6) NaCl, Kieserite, Carnallite, $MgCl_2.6H_2O$, the solution then drying up without further change.

Not only does the succession thus indicated agree with that actually found experimentally on evaporating sea water at 25°, but also very fairly with the geological succession as observed at Stassfurt. Thus the lowest deposits of rock salt represent stage 1, the overlying Kieserite and Kainite beds stages 2, 3, and 4, and the uppermost Carnallite region stages 5 and 6.

But although it is clear from the general agreement of the results

obtained in the laboratory with the observation made at Stassfurt that the temperature at which the beds were deposited was not far removed from 25°, it was possibly somewhat higher, as the proportion of Kainite, and especially of Kieserite, obtained in the laboratory is somewhat lower than that met with in nature. Moreover, whereas at Stassfurt Calcium sulphate occurs in the anhydrous form, in the laboratory it has not been obtained in this form below 32°.

The foregoing account has been compiled from a series of twenty-three papers by van't Hoff and his pupils, published since the year 1897 in the 'Proceedings of the Berlin Academy of Sciences.' Apart from these and the information given by van't Hoff in his text-books, there are only two other papers bearing on the subject—one by van der Heide ('Zeit. Phys. Chem.' **12**, 416), the other by Löwenherz (*ibid.*, **13**, 459).

Keish Caves, co. Sligo.—Interim Report of the Committee, consisting of Dr. R. F. SCHARFF (*Chairman*), Mr. R. LL. PRAEGER (*Secretary*), Mr. G. COFFEY, Professor A. G. COLE, Professor D. J. CUNNINGHAM, Mr. A. MCHENRY, *and* Mr. R. J. USSHER, *appointed to Explore Irish Caves.*

THE Committee selected for the first operations a series of caves on the slopes of Keishcorran Mountain in the county of Sligo. Owing to the unsettled state of the weather, the excavation of the caves could not be commenced until the middle of May 1901, though a preliminary survey was made early in April by Dr. Scharff and Mr. Praeger.

After careful measurements were taken a deep trench was dug across the mouth of one of the caves, so as to expose a section of the various deposits, which were as follows from above downwards :—

1. *Black earth,* containing bones of domestic animals, charcoal, and human implements (similar to those found in Crannoges), with a depth of from 6 inches to 1 foot.

2. *Breccia,* consisting of limestone blocks fallen from the roof in a tufaceous deposit. This appeared as a natural arch in the section varying from 1 foot in the centre to 3 feet at the sides, and contained numerous remains of land shells and bones of small mammals.

3. *Brown clay,* containing large blocks of limestone and numerous bones of small and a few of large mammals. At a depth of 6 feet from the surface a much waterworn block of limestone was found, indicating proximity to the floor of the cave.

As the excavation in this cave was carried to the interior it became unpromising and unsatisfactory owing to the difficulty of removing the large masses of limestone. It was therefore decided to abandon it. Datum levels having been carefully marked on the sides of the cave, it will be possible to resume work and complete the excavation should the results obtained in the other caves render it desirable.

A second cave was then opened in a similar manner, proceeding from the mouth inward, with very satisfactory results so far. Dr. Scharff, Mr. Coffey, and Professor Cole having had to return to town, Mr. Ussher was left in charge of the work, and reports that the upper stratum of this cave contained much charcoal and bones of domestic animals—broken for

the marrow—and a red deer's antler. With these were associated a stone celt, bronze pins, and portion of an iron saw of ancient pattern. Beneath the above another stratum, consisting of cave-earth, was found, in which were various remains of bear and deer, besides human teeth and charcoal.

The Committee therefore feel justified in continuing the excavations, and ask for reappointment. The collections have been deposited in the Dublin Museum, and are at present being worked out by the staff.

Erratic Blocks of the British Isles.—Report of the Committee, consisting of Mr. J. E. MARR (*Chairman*), Mr. P. F. KENDALL (*Secretary*), Professor T. G. BONNEY, Mr. C. E. DE RANCE, Professor W. J. SOLLAS, Mr. R. H. TIDDEMAN, Rev. S. N. HARRISON, Mr. J. HORNE, Mr. F. M. BURTON, Mr. J. LOMAS, Mr. A. R. DWERRYHOUSE, Mr. J. W. STATHER, *and* Mr. W. T. TUCKER, *appointed to investigate the Erratic Blocks of the British Isles, and to take measures for their preservation. (Drawn up by the Secretary.)*

THE major proportion of the records for inclusion in this report relates to Yorkshire, where an active organisation exists with working members in all parts of the county, but especially in the East Riding, where the members of the Hull Geological Society are doing admirable systematic work. In furtherance of the objects of the Yorkshire Boulder Committee an excursion to the Lake District was arranged by the Yorkshire Geological and Polytechnic Society. The area chosen for study was the country round Keswick, which is so rich in rocks of pronounced petrological characters which might be expected to have travelled over into Yorkshire. The influence of this excursion is at once to be seen in the records of erratics which have already been recognised. The peculiar rocks of Eycott Hill and Carrock Fell have been found at Dimlington, and a well characterised volcanic breccia occurring as boulders on Dunmail Raise has been found at Hornsea, along with a specimen of the well known Armboth Dyke.

A striated surface discovered on the southern slope of Skiddaw has been reported to the Committee as the only convenient method of recording an isolated but valuable observation.

The reports from the coast tract of Yorkshire continue to yield new stations for the very characteristic Norwegian Rhomb-porphyries and Elæolite-syenites. The visit paid by the geologists of Yorkshire to the Cheviots and some of its results were commented upon in the last report of this Committee. Two facts stand out in the present series of records, in the light of a more intimate acquaintance with the Cheviot rocks. While we find that many observers note the great preponderance of Cheviot porphyrites over every other type of far-travelled stones, no example of the Cheviot granite has ever been identified in Yorkshire. The Secretary has long been impressed with the singularity of this absence of evidence, and after examining the rock *in situ* has made careful search for it at Filey, Bridlington, Whitby, and other places, where the porphyrites abound. No clearly identifiable specimen could be found. A collection was made of granitic pebbles from the shore at Whitby in order to get a sufficient series to base an opinion upon. Seventy of these stones have been sliced, and the results of a preliminary examination are not

encouraging to the hope that any positive identification of the Cheviot granite can be made. The results of a fuller examination will be presented in the next report of the Committee. Meantime it may be remarked that the striking disproportion which must exist between the boulders of the Cheviot granite and those of the porphyrites will perhaps find an explanation in the conditions which prevailed in the Cheviots themselves during the time when the distribution of the erratics was in progress.

Mr. Stather's numerous records of greywackes of a similar type in various parts of Yorkshire and on the lower slopes of the Cheviots suggests the probability of their derivation from the basin of the Tweed. Two very remarkable discoveries are reported by Mr. Fearnside. The gravels of the Yorkshire Calder have long been noted for remarkable uniformity in the character of the included stones; besides local rocks there had been found nothing but well defined types of Lake District rocks, andesites, agglomerates, and the granitic rocks of the Buttermere and Eskdale types, all such as might have come by way of Lancashire from the western side of the Lake District, and perhaps one or two examples of the Galloway granites. Mr. Fearnside now adds the Norwegian Rhomb-porphyry, Brockram, brown flints, and Shap granite, discordant elements difficult to reconcile with the very consistent series previously known. Mr. H. H. Corbett, of Doncaster, points out a singular fact: the three boulders of Shap granite found respectively at Royston, Adwick, and Balby have a vein of felspar running through each of them.

The boulders recorded by Mr. Lomas from New Mills, Derbyshire, are of the type usual on that side of the Pennine Chain, but the occurrence of Triassic pebbles is of great interest, as the altitude, 930 feet, is several hundreds of feet above that of any Triassic rock *in situ* in the region.

The boulders of nodular dolerite recorded from the Ayrshire coast precisely resemble those which are found in considerable numbers in Western Lancashire and Cheshire, especially in the Wirral. A single example has been found from the north of Ireland. These rocks have long been regarded as of Scottish derivation, and their great abundance on the coast of Ayrshire seems to favour the supposition. It is to be hoped that some geologist may be found in Glasgow who can identify the rock and state its source.

The Secretary has provided the Lincolnshire Boulder Committee with a series of rock specimens from Norway and the Cheviots to serve as types for the determination of the source of erratics, and he has still remaining a large number of duplicate specimens of noteworthy Norwegian rock (Rhomb-porphyries, Elæolite-syenites, &c.), rocks from the Cheviots, the south of Scotland, and from the Lake District, which he is prepared to distribute to local museums or to individuals willing to aid in the work of this Committee.

CUMBERLAND.

Reported by Mr. JOHN CARLTON (*Hull Geological Society*) *per Yorkshire Boulder Committee.*

Skiddaw.—On left of pathway to top of Skiddaw, about 30 yards above second hut, 1,450 feet above Keswick, glacial striæ were observed on solid slate from which the turf had been recently removed. Direction W.S.W.

Derbyshire.

Reported by J. Lomas, *Esq., A.R.C.S., F.G.S., Broadhurst Edge, near Jordan Arms, New Mills.* 930 *feet O.D.*

Andesitic ash, 14 inches in diameter.
Many striated fragments of fine micaceous grit.
Rhyolite (from Upper Barrowdale Series).
Buttermere granophyre (common).
Coarse millstone grit, 2 feet diameter.
Porphyritic felsite.
Triassic quartzite pebbles.

Lancashire.

Reported by J. Lomas, *Esq., A.R.C.S., F.G.S.*

Liverpool.—At Sandon Graving Dock. In boulder clay 17 feet thick.

Diorite, 3 ft by 2 ft. 6 in. by 1 ft. 6 in. Axis nearly N. and S. Well scratched and exhibiting a well developed sole. It lies *in situ* 5 feet below Old Dock Sill.
Diorite, 2 ft. 10 in. by 2 ft. by 1 ft. 8 in. Axis N. 5° E.
Andesitic agglomerate, 1 ft. by 1 ft. by 9 in.; 16 feet below O.D.S.
Limestone, 1 ft. in diameter.
Keuper marl. Various small pieces.
Gypsum abundant.

Lincolnshire.

Reported by Rev. E. Adrian Woodruffe Peacock.

Cadeney Manor House.—Boulders found in sinking a well.

Coarse augen gneiss in dark boulder clay at 18 feet.
Grey limestone with brown ferruginous oolitic grains and shell of a *Lima*; not *L. gigantea* or *L. laeviuscula*, though belonging to the same group. ? Neocomian or Lias.
Dolerite; Limestone probably *L. Lias*; grey felspathic sandstone; dark grey shale; red chalk.

Reported by Messrs. Paul Davis *and* J. W. Stather, *F.G.S.* (*Hull Geological Society*), *per Yorkshire Boulder Committee.*

Cleethorpes.—Three large clay pits near the railway station show Boulder Clay 30 to 40 feet thick. The boulders, many hundreds of which are visible, are of the usual East Yorkshire types, but of smaller average size. Among those noted were rhomb-porphyry; elæolite-syenite; Cheviot porphyrites; greywacke sandstone; hypersthene-dolerite of Eycott Hill; grey, black, pink, and green-coated flints.

Yorkshire.

Reported by the Yorkshire Boulder Committee (J. H. Howarth, *F.G.S., Secretary*).

By G. A. Auden, *Esq.*

Dringhouses, York.—

Carboniferous sandstone, two large boulders, one weighing 3–4 tons, obscurely striated.

By E. HAWKESWORTH, *Esq.*

Brompton, near Northallerton.—

The turnpike road from Northallerton to Stockton cuts through a ridge of drift just before reaching the village. It yielded 1 rhyolite: 1 dolerite; 1 gabbro (?); 2 Carboniferous Limestones (black) and Carboniferous sandstones.

By W. GREGSON, *Esq., F.G.S.*

Kirklington, 6 miles N.E. of Ripon, at Coldstone House Farm.—

1 galliard or ganister, 4 ft. by 2½ ft. by 2 ft. subangular; top smoothed and grooved; striæ N. and S.

By W. G. FEARNSIDE.

Horbury, near Wakefield.—In an excavation for the south pier of a bridge over the river Calder.

3 Shap granite.
1 Brockram.
1 Rhomb-porphyry.
1 Brown flint.

The boulders were taken up in the scoop of a dredger along with a portion of basal clay when excavating for the concreting of the foundations of the bridge pier.

By P. F. KENDALL, *F.G.S.*

Settrington, Vale of Pickering.—In fields about half a mile S.W. of railway station a thin scattering of foreign pebbles occurs among the fragments of the subjacent Oölite. Twenty were collected: they include:—

1 Vein quartz pebble, (?) Trias.
6 Saccharoid quarzites, one liver-coloured, (?) Trias.
2 Carboniferous sandstone, one felspathic.
1 Red jasper.
4 Flints.
1 Fine-grained gneiss (?).
1 Basalt.
1 Sandstone } (? local).
1 Limestone }

By E. HAWKESWORTH, *Esq.*

Wighill, near Tadcaster.—Taken from material excavated in making a drain.

2 Dolerites; 1 chert.

Kettleness, near Whitby.—On beach just south of Kettleness.

1 Cheviot porphyrite; 1 elæolite syenite.
1 Gneiss.

Wykeham, Vale of Pickering.—From gravel-pit.

1 Dolerite; 1 Cheviot porphyrite.
1 Cheviot andesite; 2 grey flints.
1 Elæolite-syenite, (?) a small pebble.

Communicated by the Boulder Committee of the Hull Geological Society.

Ayton, near Scarboro'.—

1 Rhomb-porphyry.

Hutton Bushell, Vale of Pickering—In gravel-pit at east end of village.

1 Rhomb-porphyry.

Wykeham, Vale of Pickering.—In sand-pit behind the Downe Arms Hotel.

Cheviot porph rite; Lias.

Seamer.—In glacial gravel in pit contiguous to railway station.

Rhomb-porphyry; Cheviot porphyrite; basalt: red granite, magnesian limestone (Roker type); Carboniferous limestone; black flint Lias; and much sandstone from local sources.

Etton, near Beverley.—In strong Boulder Clay at east end of the village.

Cheviot porphyrite (several varieties).
Greywacke sandstone; Lias, &c.

Gardham, near Beverley.—A shallow pit in chalky gravel west of the village contained a few foreign pebbles, among which Cheviot porphyrites were predominant. Basalt-Carboniferous limestone was also noted.

By THOMAS SHEPPARD, *Esq.*, *F.G.S.*

Meaux, near Beverley.—

Rhomb-porphyry; Cheviot porphyrite; Carboniferous limestone and sandstone; Lias.

By J. W. STATHER, *Esq.*, *F.G.S.*

Leconfield, near Beverley.—In old gravel-pit east of Pump Bridge. Gravel consisting of chalk with a few foreign pebbles, chiefly Cheviot porphyrites and greywacke sandstone.

Cherry Burton, near Beverley.—Chalk capped with 8 feet of Boulder Clay half-mile east of station. Among the pebbles of non-local rocks in the clay Cheviot porphyrites greatly preponderate. Basalts are also plentiful. Greywacke sandstone and Lias were also noted.

Bartindale Farm, near North Burton.—Fifty yards east of house.

Basalt, 4 ft. by 3 ft. by 3 ft.

Grindale-on-the-Wolds.—Many boulders occur in this neighbourhood, and a pavement has been made of them at Field Spring. Basalts are the most common.

Dimlington.—

1 Dolerite, Eycott Hill.
1 Gabbro, Carrock Fell.

Ferriby Common, near Hull.—Chalky gravel in a small pit on the Humber side contains a small percentage of foreign rocks, including rhomb-porphyry ; basalt ; Carboniferous limestone.

Thornton Dale, Vale of Pickering.—In the cutting east of the station, through beds mapped as glacial, no trace of foreign rocks seen ; all local Oolite.

By F. F. WALTON, *F.G.S.*

Hornsea.—

1 Volcanic breccia, 4 in. by 3 in. by 3 in., identical with boulders found in stream at Dunmail Raise, Cumberland.
1 Quartz porphyry (Armboth Dyke), 4 in. by 3 in. by 3 in.

SCOTLAND.

AYRSHIRE.

Reported by P. F. KENDALL, *F.G.S.*

A nodular dolerite closely resembling boulders found in Western Lancashire and Cheshire forms many boulders on the shore at Shalloch, one mile south of Girvan. The boulders appear rather less numerous at Girvan, and at West Kilbride only one has been found.

Boulders of the Ailsa Craig Riebeckite-eurite are very abundant along the coast from Girvan to Ballantrae, but I have not found it at West Kilbride.

Life-zones in the British Carboniferous Rocks.—Report of the Committee, consisting of Mr. J. E. MARR (*Chairman*), Dr. WHEELTON HIND (*Secretary*), Mr. F. A. BATHER, Mr. G. C. CRICK, Dr. A. H. FOORD, Mr. H. FOX, Professor E. J. GARWOOD, Dr. G. J. HINDE, Professor P. F. KENDALL, Mr. J. W. KIRKBY, Mr. R. KIDSTON, Mr. G. W. LAMPLUGH, Professor G. A. LEBOUR, Mr. B. N. PEACH, Mr. A. STRAHAN, *and* Dr. H. WOODWARD. (*Drawn up by the Secretary.*)

THE suggestions of the Secretary, published in the last report of the Committee, that the faunas of (*a*) the beds which occur between the Millstone Grits and the Massif of Limestone in the South Pennine area, and (*b*) the faunas which occur in the shales between the Millstone Grits and the upper beds of Limestone in the North Pennine area should be examined, was carried out by placing a collector in the Pendle district and one also at Hawes. The Committee have been most fortunate in obtaining the skilled services of Messrs. Rhodes and Tait, collectors on the Staff of the Geological Survey, while on vacation, and Mr. Rhodes has collected in the beds between the Underset Limestone and the Millstone Grits around Hawes, and Mr. Tait has collected in the beds between the Clitheroe and Chipping, inliers of Massif Limestone and the Millstone Grits.

Mr. Rhodes has sent several sections shown by the streams examined by him, which are appended, and the fossils he has collected are shown in tabular form. The results of Mr. Tait's collecting are also shown in tabular form, and a comparison of the two sets of fossils is most instructive; for while Mr. Rhodes' specimens are all members of the fauna of the Carboniferous Limestone, in the Pendleside fauna only a few Brachiopods are common to it and the Carboniferous Limestone.

The work done by these collectors largely confirms the results expressed in the paper read before the Geological Society last February by the Secretary to this Committee and Mr. J. A. Howe, which has just appeared in the 'Quarterly Journal' of the Society. Mr. Tait has traced the Pendleside fauna over a wider extent of country locally. Lately the writer has obtained this fauna, at the same horizon, in North Staffordshire and Derbyshire. It is an interesting fact that he has this year obtained *Chænocardiola* (*Lunulacardium*) *Footii* and *Posidonomya membranacea* in these beds, hitherto only known from the Upper Limestone shales of Ireland.

The great point of interest in Mr. Rhodes' collection is the finding in Edendale of many species, hitherto only found in the shales of the Carboniferous Limestone series of Scotland: *Parallelodon semicostatum*, *Nucula luciniformis*, *N. oblonga*, *Nuculana lævistriata*, *Protoschizodus impressus*, *Cypricardella annæ*, *C. rectangularis*, *Sanguinolites plicatus*, *S. variabilis*, *Sedgwickia scotica*, *Entolium Sowerbyi*, *Euomphalus carbonarius*, *Hyalostelia parallela*, and *Serpulites membranacea*.

This fact is important as an aid to correlation of the Limestone series of Scotland with portions of the Carboniferous series of England.

The Cephalopoda have been submitted to Dr. Foord and Mr. Crick, the Sponges to Dr. G. J. Hinde, the Crustacea to Dr. H. Woodward. The Secretary has determined the Lamellibranchiata and Brachiopoda.

Dr. A. H. Foord reports about the Cephalopoda sent from Mr. Rhodes' series: 'They clearly represent an horizon high up in the Carboniferous, *i.e.*, that of the Upper Limestone group of the Scottish Carboniferous Limestone series. The species I particularly refer to are *Orthoceras sulcatum* (Flem.), *Cyrtoceras* (*Meloceras*) *rugosum* (Flem.).' The Lamellibranchiata and small Gasteropoda strongly confirm this view. At the same time the absence of the Pendleside fauna both in Scotland and the North of England is important. The typical Cephalopoda and Lamellibranchiata of this group have not yet been found as a fauna where the Scotch type of fauna occurs. The Pendleside fauna has been obtained in beds of the same series at several places in S.W. Yorkshire, N. Staffordshire, Cheshire, Derbyshire, and Co. Dublin, and the characteristic zone-forms appear to be: *Glyphioceras reticulatum*, *G. bilingue*, *G. spirale*, *Dimorphoceras Gilbertsoni*, *G. Loonyi*, *Gastrioceras carbonarius*, *G. Listeri*, *Orthoceras Steinhaurei*, *Aviculopecten papyraceus*, *Posidonomya Becheri*, *P. membranacea*, *P. corrugata*, *Posidoniella lævis* and *P. minor*, *Nuculana stilla*, *Schizodus antiquus*, *Chænocardiola Footii*, *Leiopteria longirostris*, *Macrocheilina Gibsoni*, *M. reticulata*, *M. elegans*.

It is interesting to note that Mr. Rhodes found *Productus giganteus* and *P. latissimus* as high as the Main Limestone in the Hawes district, and that he obtained *P. giganteus* and *Chætetes septosus* with *Lithostrotion* plentifully 33 feet over the Hardraw Scar Limestone at Mill Gill, Asgrigg, and I have lately obtained all three in the Main Limestone of Weardale.

List of Sections from which Mr. RHODES *collected.*

A

Notes on* SECTION A. *Far Cote Gill. 1-in. Survey, Sheet 40. 6-in. Sheet 36. Westmorland. Beds seen from base of Underset Limestone to Crow Limestone.

		Ft.	In.
	Ganister	4	0
	U. Limestone. ? Thickness, say	35	0
40–98	Hard dark calcareous shale on impure Limestone top of U.L.	4	0
	Blue shale with Ironstone nodules	5	0
	Rotted sandy shale, about	7	0
	Sandstone false-bedded, with sandy shale, about	15	0
	Main Limestone disturbed. ? Thickness	? 25	0
	Top of above not seen	-	-
Fossils from upper foot (10-fathom Grit), 1–39.	Impure grey flaggy Limestone	2	0
	Dark unfossiliferous sandy shales and sandstones	? 50	0
	LITTLE LIMESTONE, grey crystalline Limestone, traces of encrinites	2	0
	Grey chert streaked with black, sponge spicules	2	0
	Thin nodular bed. ? Phosphatic	0	3
99–113	Blue shale with Ironstone nodules and pyrites	6	0

B

Little Limestone, Smithy Gill. E. slope of Swarth Fell. 1-*in. Survey, Sheet* 40. *Westmorland.*

		Ft.	In.
UNDERSET LIMESTONE.	Blue Grey Limestone, with chert nodules	6	0
Productus giganteus.	Coral Limestone (turbinate Corals)	2	0
	" (Lithostrotion ? junceum), varies from 1 to	3	0
	Grey blue Limestone	6	0
	? Several feet covered	—	
	Top bed seen in Gill bed	2	0
	Grey and black chert bed, with sponge spicules	2	0
	Rotted shales	10	0
	Covered. ? Feet	—	
	Sandstone false-bedded	14	0
Productus giganteus, very rare; and occasional turbinate Corals	MAIN LIMESTONE. ? Thickness, but probably not more	20	0
	Top showing in stream	—	
	Rotted. ? Calc. shales	2	0
	Rotted shale	8	0
Fossils from upper foot, 114–147.	LITTLE LIMESTONE, impure grey Limestone	2	0
	Rotted shale	? 6	0
	Sandy shale and sandstones directly resting on above	—	

C

Goodham Gill. E. slope of Swarth Fell. 1-*in. Survey, Sheet* 40. 6-*in. Sheet* 49. *Yorkshire. U. Limestone. Base not seen.*

		Ft.	In.
UNDERSET LIMESTONE.	Coral reef seen and collected from, about	5	0
	Other part of Limestone obscure	—	

		Ft.	In.
	Hard grey silicious shale on Limestone	1	0
	Soft shale covered in little waterfall	1	0
Fossils from top foot.	Hard silicious flaggy shale	3	0
	Grey crystalline Limestone	1	4
	Grey and darker chert bed, with sponge spicules	3	0
	Limestone bluish grey	0	6
	Dark chert spicules	0	6
	Black chert spicules	1	0
	Hard blue silicious Limestone	1	0
	About 10 feet of beds covered	10	0
Fossils	Calcareous shales at base of second waterfall at gorge	3	0
	Dark sandy shale (micaceous) with lenticles of sandstone	25	0
	False-bedded sandstone	20	0
Productus giganteus. Very rare.	MAIN LIMESTONE	? 30	0
	Calcareous shales, thin band rotted	0	6
	Marked shale, probably	4	0
LITTLE LIMESTONE series.	Dark calcareous shale (flaggy).	6	0
	Impure Limestone, with silicious bands and encrinite ossicles	1	0
	Hard grey Limestone, with encrinite ossicles	2	0
	Shale black and micaceous	1	6
	False-bedded sandstone	? 2	0
	Dark sandy shale, with pyrites	4	6
	Sandy shale, false-bedded sandstone ripple-marked at top	40	0
Fossils	Calcareous sandstone, marine band	1	0
	Rotted sandy shale	2	0
	Crow Limestone, grey crystalline L., traces of encrinite ossicles	2	0
Fossils ?	Hard silicious flaggy shale with Cauda Galli	3	0
	Blue shale, over above not seen in junction, but higher up stream 4 feet seen, and yielding Ironstone nodules	4	0
	Above this sandy micaceous shales, probably with occasional Ironstone nodules	60	0

Goodham Gill Sections.—From Underset Limestone to probable Base of Millstone Grit.

		Ft.	In.
UNDERSET LIMESTONE.	U. Limestone	? 25	0
	Hard grey silicious shale top of U.L.	1	0
	Soft shale shown under bed of stream	1	0
	Hard silicious flaggy shale (fossils)	3	0
	Grey crystalline Limestone	1	4
	Grey and dark chert bed, with sponge spicules	3	0
	Limestone bluish grey	0	6
	Dark chert (sponge spicules)	0	6
	Black chert ,,	1	0
	Blue hard silicious Limestone	1	0
	About 10 feet of beds covered	10	0
	Calcareous shales base of waterfall (fossils)	3	0
	Dark sandy shales, with some flaggy sandstone near top	25	0
	False bedded sandstones to base of Main Limestone	20	0
MAIN LIMESTONE	MAIN L. (with occasional *Productus giganteus* and Corals) ?	30	0
	Calcareous shale	0	6
	? About 4 feet of shales. ? Covered	4	0
	Hard dark silicious shales	6	0
	Limestone with silicious bands	1	0
	Hard grey Limestone with encrinite ossicles	2	0

		Ft.	In.
	Shale black and micaceous	1	6
	Sandstone false-bedded	2	0
	Dark sandy shales with pyrites	4	6
	Hard grit on sandstone bed	2	6
	Sandy micaceous shales with lenticles of sandstone in upper part	8	0
	Sandstone more or less false-bedded and ripple-marked in upper part	? 30	0
	Calcareous grit (?) fossiliferous	1	0
	Rotted shale	2	0
LITTLE LIMESTONE.	Blue-grey silicious Limestone	2	0
	Hard silicious flaggy Limestone	1	0
	Hard silicious shale with Cauda Galli	2	0
	Shales with Ironstone nodules rotted. ? About	6	0
	About 14 feet of shales covered. ? Same as above	14	0
	Dark micaceous sandy shales (iron nodules)	60	0
	Dark and more sandy shales with one or two flaggy bands in upper part and irregular calcareous sandstone masses	40	0
	Irregular flaggy sandstone ripple-marked, and with annelid tracks	25	0
	Massive grit with ganister-like top, rootlets in top beds	? 20	0
	Shale-rotted	? 4	0
	Impure nodular Limestone band with cyprids	0	6
	Blue rotted shales with some Ironstone nodules	? 20	0
	Grey ganister (rootlets), about	0	4
	Coal seam, silicified (?), 6 in. to 1 ft.	1	0
	Hard silicious flaggy beds with fossils	4	0
	? Base of Millstone Grit	—	

D

Lund's Gill Sections.

		Ft.	In.
UNDERSET LIMESTONE.	U. Limestone	20	0
	Dark blue flaggy silicious Limestone (fossils)	12	0
	Grey and black chert	6	0
	Grey silicious Limestone	1	0
	Blue chert	0	8
	Grey silicious Limestone	1	0
	Blue Limestone	1	6
	Calcareous shales. ? *Spirifera glabra* common	3	0
	Blue shale with Ironstone nodules	4	0
	Dark sandy shale with Ironstone nodules	8	0
	Dark sandy shale passing up into sandstones	12	0
	False-bedded sandstones	20	0
MAIN LIMESTONE	MAIN LIMESTONE grey and compact lower part	25	0
	„ middle part coarsely encrinital	25	0
	„ upper part compact encrinital	25	0
	Sandy shales and flagstones, flags ripple-marked	20 to 25	0
	Ganister-like grit	1	6
LITTLE LIMESTONE.	LITTLE LIMESTONE blue (small encrinite ossicles)	2	0
	Dark silicious flaggy beds with Cauda Galli	1	6
	Rusty layer glauconitic and containing ? calcareous sponge spicules	0	3
	Silicious shales	1	0
	Blue shale with Ironstone nodules	10	0
	Sandy shales with Ironstone nodules	15	0
	Sandy shales with some thin flags in upper part	30	0
	Dark sandy shales and flags interbedded. (?) Probably	100	0

E

Cartmere Gill, E. Baugh Fell, Grisedale. 1 *in. Sheet* 40. 6-*in. Sheet* 49. *Yorkshire.*

		Ft.	In.
LITTLE LIME-STONE.	L. Limestone. Blue Limestone	2	6
	Black and grey silicious beds	3	0
	Dark shales	—	
	Crow Limestone (encrinital Limestone)	5	0

Round Ing Gill, Grisedale. Sheet 40, 1-*in. Sheet* 49^{8} 6-*inch Map. Yorkshire.*

	Ft.	In.
MAIN LIMESTONE	?	—
Calcareous shale	3	0
Blue shale	9	0
Hard flaggy silicious Limestone beds	2	0
Dark sandy shale	9	0
Sandstone	?	
LITTLE LIMESTONE not seen.		
The thick sandy shale banks not in good position for working.		

G

Fluot Gill, Grisedale. 1-*in. Sheet* 40. 6-*in. Sheet* 49^{8}. *Yorkshire.*

	Ft.	In.
MAIN LIMESTONE	? 25	0
Sandy shales and sandstones. Sandstone ripple-marked	? 25	0
LITTLE LIMESTONE. Blue compact Limestones (on sandstone)	2	0
Hard cherty Limestone	2	0
Cherty shale not clear	3	0
Rotted shales, mostly covered	12	0
Sandy shales with fossils (and Ironstone nodules)	70	0
Calcareous sandstone masses and thin flags and shales	25	0
Sandy micaceous shales	? 10	0
Impure Limestone not in place—slipped (? represents CROW LIMESTONE)	2	0

Section over H.S. Limestone.—Mill Gill above Mill Gill Force, Askrigg. 6 *in* 66, *N.E.*^{w} *Yorkshire Section above Hardra Scar Limestone.*

		Ft.	In.
	HARDRA SCAR LIMESTONE, probably	60	0
	Calcareous shale (encrinite ossicles)	0	6
	Thin calcareous band weathering brownish red	0	2
	Blue shale	1	0
	Irregular sandstone and sandy shale partings	28	0
	Carbonaceous shale with coaly streaks and plant remains	1	0
	Grit band with plant impressions	0	6
	Carbonaceous shale, plant remains	0	9
	Blue shale	1	0
Fossils.	Calcareous band, with parts Limestone Corals, &c.	1	0
	Hard compact hydraulic Limestone	2	0
	Hard shale band (? with Posidonomya not well preserved)	0	2
	Hard compact hydraulic Limestone	2	0

Mr. Rhodes' collecting in the Hawes Area.—Table A.

A—Farcote Gill.
B—Smith's Gill.
C—Goodham Gill.
D—Lund's Gill.

E—Cartmere Gill }
F—Round Ing Gill } Grisedale.
G—Fluot Gill }
H—Nine Standards Fell, Faraday Gill.

The Cephalopoda have been determined by Dr. A. H. Foord; Sponges by Dr. G. J. Hinde; the other specimens by Dr. W. Hind.

—	Underset Limestone	Beds above	Main Limestone	Beds above	Little Limestone	Beds above	Crow Limestone to Base of Millstone Grits
Porifera							
Hyalostelia parallela (M'Coy)	—	—	—	—	—	—	E
Hexactinellid spicules . .	—	A	—	—	A D	—	E C
Monactinellid spicules . .	—	A	—	—	A D	—	E C
Tetractinellid spicules . .							
Echinodermata							
Crinoid joints	—	D	—	—	—	—	E
Annelida							
Serpulites membranacea (M'Coy)	—	A	—	A	—	G D	
Arthropoda							
Entomoconchus Scouleri .	C						
Polyzoa							
Glauconome grandis . .	—	A					
Fenestella	C	A					
Polypora dendroides (M'Coy)	—	D					
Brachiopoda							
Athyris ambigua . . .	C	—	—	—	—	—	H
„ planosulcata . .	C	A C					
„ expansa . . .	—	D					
Camarophoria globulina .	C	—	—	F			
Chonetes laguessiana . .	C	—	—	A F	B		
Dielasma gillengensis . .	C						
„ hastata . .	C						
Discina nitida . . .	—	—	—	A	—	—	H
Lingula squamiformis . .	—	A D	—	A F	B		
„ mytiloides . .	D	—	A F	—	—	—	C
Orthis resupinata . . .	—	D					
Productus aculeatus . .	C						
„ giganteus . .	A B C	—	A B C				
„ longispinus . .	C	C D	—	F			
„ scabriculus . .	—	—	—	—	—	—	C
„ semireticulatus .	C	A C D	—	F	B C	—	C H
„ punctatus . .	C	A C	—	—	—	—	H
„ undatus . .	—	—	—	A			
Retzia radialis . . .	—	—	—	(F ?)			
Rhynchonella acuminata .	C						
„ pleurodon .	—	A C	—	A F	B	—	C
Spirifer crassus . .	—	C D	—	C	C	F	
„ glaber . . .	C	D	—	—	—	—	C
„ lineatus . . .	C	A C	—	—	C		
„ ovalis . . .	—	C	—	—	—	—	C H
„ trigonalis. . .	—	C D	—	A (F ?)	B C		
„ striatus . . .	—	—	—	A			

Mr. Rhodes' collecting in the Hawes Area.—Table A (continued).

—	Underset Limestone	Beds above	Main Limestone	Beds above	Little Limestone	Beds above	Crow Limestone to Base of Millstone Grits
Streptorhynchus crenistria .	— —	— —	— —	F A	B E —	— G D	C H
Lamellibranchiata							
Aviculopecten . . .							
„ segregatus .	A						
„ sp. .							
Entolium Sowerbyi . .	D	C	A	C			
Leiopteria lunulata . .	A C						
Pinna mutica . . .	—	A D		D			
Pleronites angustatus . .	—	C					
Cypricardella annæ . .	—	H					
„ rectangularis .	—	H					
Ctenodonta lævirostris . .	—	A H	A	F	—	A D G	
Edmondia Maccoyi . .	—	—	—	C F			
„ sulcata . . .	—	--	—	C F			
„ sp. . . .	—	—	—	—	—	E D G	
„ unioniformis ? .	—	C					
„ Lyelli . . .	—	A					
Lithodomus lingualis . .	—	A	—	—	B		
Myalina	—	—	—	F			
Nucula gibbosa . . .	—	D	A				
„ luciniformis . . .	—	A D	—	—	—	GDEC	
„ oblonga . . .	—	A	—	—	—	E D G	
Nuculana attenuata . .	—	D H	—	A	—	E C G	
„ lævistriata . .	—	—	—	—	—	C G	
Parallelodon reticulatum .	—	—	—	—	B		
„ semicostatum .	—	A D		E			
Protoschizodus axiniformis .	—	C	—	E	B		
„ impressus .	—	—	A	—	B		
Sanguinolites angustatus .	—	A					
„ plicatus . .	—	—	—	—	B		
„ tricostatus .	—	C					
„ variabilis .	—	—	—	C	E	DECG	
Scaldia Benedeniaria . .	—	B	—	E	B		
Sedgwickia scotica . .	—	C					
Solenomya primæva . .	--	C					
Gasteropoda							
Euomphalus carbonarius .	—	D	—	A			F
Natica plicistria . . .	—	D	C	—	A		
Bellerophon decussatus var. striatus . .	—	—	—	—	—	G C	
„ Urei . . .	—	D	—	—	A C	D C G	E
Cephalopoda							
Cyrtoceras (Meloceras) rugosum	—	—	—	C			
Orthoceras cf. Morrisianum	—	A	—	—	D	A E D	
„ sulcatum . .	—	A	—	—	—	G	
Pleuronautilus nodosocarinatus	—	—	—	—	B		
Vestinautilus sp. . . .	—	—	—	—	—	D	
Incertæ sedis							
Conodonts (fragmentary) .	—	—	—	—	D		

Pendle Hill Area, Mr. Tait's collecting.—Table B.

—	Pendleside	Dinckley Hall River Ribble	Ramsclough Thornley Hall	Black Hall Bolland	Cold Coates Bolland	West Bradford Bolland	Holden, Bolland	Sulber Lathe Flasby
Plantæ								
Lepidodendron vettheimianum . .	*							
Asterocalamites scrobiculatus . .	*							
Crustacea								
Ceratiocaris sp. . .	*							
Corals								
Zaphrenties Enniskilleni ? . . .	*					*		
Brachiopoda								
Athyris ambigua .	*					*	*	*
Chonetes laguessiana	*							*
Lingula mytiloides .	*							
Orthis Michelini .	*							
Productus cora . .	*							
„ punctatus.	*							
„ scabriculus	*							
„ semireticulatus .	*					*		
Rhynchonella trilatera	*							
Spirifer (fragments) .	*					*		
Streptorhynchus crenistria . . .	*					*		
Lamellibranchiata								
Actinopteria persulcata . . .		*	*					
Aviculopecten Decheni	*	*					*	*
Pterinopecten (Aviculopecten) papyraceus . .	*						*	
Ctenodonta lævirostris	*							
Myalina peralata .		*						
Posidonella lævis .	*	*		*	*			*
„ minor .	*							
Posidonomya Becheri	*	*	*	*	*		*	*
„ corrugata		*						
„ membranacea		*						
Solenomya costellata.								
Cephalopoda								
Glyphioceras bilingue	*							*
„ reticulatum	*	*			*		*	*
Orthoceras cf. Morrisianum	*	*					*	*
Prolecanites compressus	*							
„ serpentinus		* ?			* ?		* ?	

The Structure of Crystals.—Report of the Committee, consisting of Professor N. STORY MASKELYNE (*Chairman*), Professor H. A. MIERS (*Secretary*), Mr. L. FLETCHER, Professor W. J. SOLLAS, Mr. W. BARLOW, Mr. G. F. HERBERT SMITH, *and the* Earl of BERKELEY, *appointed to report on the Present State of our Knowledge concerning the Structure of Crystals.* (*Drawn up by* Mr. BARLOW *and* Professor MIERS, *assisted by* Mr. HERBERT SMITH.)

PART I.

Report on the Development of the Geometrical Theories of Crystal Structure, 1666–1901.

THE problem of the structure of a crystal presents itself under two aspects; it involves the consideration (1) of the material which constitutes the crystal, and (2) of the manner in which this material is put together. To the first part of the inquiry belong all speculations and observations which relate to the nature of the crystal unit: as to whether it be a chemical molecule or an aggregation of chemical molecules; what may be its dimensions and regularity or irregularity; and what forces co-operate to fix its position and orientation.

It might reasonably be supposed that this part of the inquiry should precede that which relates to the arrangement of the material. In reality, however, very little is known about the actual nature of the ultimate particles of matter in the solid state, and much more is known about the manner in which it must be arranged. For, as the study of crystals has progressed, it has been found that their morphological and physical regularity results from the fact that they are homogeneous; both the law of rational indices, which regulates the disposition of the faces of a crystal, and the æolotropism, which regulates its physical characters, are in harmony with the geometrical properties of a homogeneous structure.

Now the distribution of the material in a homogeneous structure may be studied as a geometrical problem quite independently of the nature of the material, for it may be treated as the problem of the homogeneous partitioning of space (see below, p. 310).

The present portion of the report, therefore, deals exclusively with the geometrical theory of the homogeneous partitioning of space, or (what comes to the same thing) the homogeneous repetition of identical parts in a uniform structure; a side of the subject which seems to have reached something like finality.

A second part will be concerned with the nature of the ultimate particles and with the possible arrangements corresponding to actual substances, a side of the subject which presents considerable difficulty and may be said to be still in its infancy.

In order to put before the reader a clearer and more satisfactory idea of the present state of our knowledge, the historical development of the subject is sketched below, and the more important contributions to this development are discussed in detail. It will thus be perceived that continual progress has been made towards a clearer comprehension of the possible ways in which the homogeneous repetition of parts may take place, each

advance being suggested or confirmed by the knowledge obtained from the investigation of the morphological and physical characters of crystals. Since the means at our disposal do not admit of the proof of the existence of similarly repeated parts in crystals by direct observation, any such proof must necessarily be indirect, and, to be conclusive, the properties of homogeneous structures mathematically deducible must be shown to be in complete harmony with those actually observed in crystals.

Early Views.

Many of the physical properties of matter may be explained without any idea of structure or grain, and some physicists have so defined homogeneity;[1] but such definitions merely ignore and do not preclude the conception of a homogeneous repetition of definite parts.[2] Indeed, the call for such a conception seems imperative. Without structure it would be difficult, for example, to explain the striking polarity displayed by such a mineral as tourmaline. From considerations based upon known facts in physics and chemistry, it has been shown that the dimensions of the atoms, or, perhaps, the distances between their centres, though extremely small, must lie within definite limits.[3]

That by the packing together of similar bodies artificial systems may be obtained whose symmetry of form closely resembles that of certain crystals was perceived nearly two-and-a-half centuries ago by Robert Hooke from a study of the forms presented by alum. Thus he says: 'I think, had I time and opportunity, I would make probable, that all these regular Figures, that are so conspicuously *various* and *curious* . . . arise only from two or three positions or postures of *Globular* particles, and those the most plain, obvious and necessary conjunctions of such figur'd particles that are possible. . . . And this I have *ad oculum* demonstrated with a company of bullets and some few other very simple bodies; so that there was not any regular Figure, which I have hitherto met withal, of any of those bodies that I have above named, that I could not with the composition of bullets or globules and one or two other bodies, imitate, even almost by shaking them together.'[4]

Just after Hooke had put forward his idea, evidence of the regularity of crystal structure was supplied by the observation of Nicolaus Steno,[5]

[1] *Cf.* the definitions given by Biot in 'Mémoire sur la Polarisation lamellaire,' *Mém. Acad. Sci.*, 1842, xviii. p. 633, and by Thomson and Tait in *Natural Philosophy*, § 675.

[2] The following definition of a crystal, based exclusively on physical behaviour, was first enunciated by Groth: 'A crystal is a homogeneous solid body whose elasticity differs in different directions within it' (*Ber. d. Berliner Ak.*, 1875, p. 549). As Schönflies remarks, it is now generally admitted that the constancy of the crystal substance is revealed by its physical properties rather than by its external form, the latter being indeed more or less fortuitous and dependent on the conditions of growth (see Schönflies *Krystallsysteme und Krystallstructur*, p. 5).

[3] Lord Kelvin (Sir W. Thomson), *Nature*, 1870, vol. i. pp. 551–553, reprinted Appendix F, 'Natural Philosophy,' by Thomson and Tait. It is interesting to note that certain of Jordan's groups of movements, in which some of the minimum distances separating similarly repeated ultimate parts are infinitesimally small as compared with the others, are incompatible with the symmetry of actual crystal forms, *i.e.*, forms obeying the law of rational indices (see below, p. 312).

[4] *Micrographia*, London, 1665, p. 85.

[5] *De solido intra solidum naturaliter contento dissertationis prodromus*, Florentiæ, 1669 (English translation, London, 1671).

that the mutual inclinations of corresponding faces of rock-crystal are the same in different specimens.

It was seen that the property of cleavage also points to the uniform repetition throughout a crystal of a definite structure of some kind, and various suggestions as to the forms of ultimate particles were based upon the cleavage. Thus Guglielmini,[1] who also studied the forms of alum, argued the existence of plane faces for these particles, and attributed crystal forms to them. This observer, relying on the uniformity of internal structure, was the first to affirm that crystals of the same substance must always cleave in the same directions. Westfeld[2] suggested that calc-spar is composed of rhombohedral particles. The latter idea was adopted and extended by Gahn and Bergmann,[3] who thus anticipated the general theory of crystal structure put forth by the Abbé Haüy, to which reference will be made immediately.

Shortly prior to Haüy we have the important discovery made by Romé de l'Isle[4] that the various shapes of crystals of the same natural or artificial product are all intimately related to each other, and can be derived from a certain fundamental figure called the *primitive form*, the shape and angles of which are proper to the substance. The variety of form is due to the variety of the secondary faces. De l'Isle himself seems to have supposed that the secondary faces have absolutely arbitrary positions, except so far as they are fixed by symmetry of mere external form. His work, by directing attention to the invariable nature of the crystal substance, and to the striking contrast between this invariability and the variety of external form which may be exhibited by the same body, supplemented the evidence in the same direction afforded by optical and physical properties.[5]

Haüy.

It is now rather more than a century since René Just Haüy suggested an intimate relation between the forms of crystals and the arrangement of their ultimate parts, and thus placed the study of crystal structure on a sure foundation. The stimulus given to research by his labours has been enormous; multitudes of facts supporting his principal conclusions have been accumulating ever since his day; and it is not too much to say that nearly all the subsequent work on the subject has been but an expansion or modification of the work done by him.

Haüy bases his conclusions as to the nature of the crystal unit, or molecule, entirely on the phenomena of cleavage. In any given crystal which displays this property he determines the shape of the similar polyhedra which would be obtained by separating the mass along cleavage planes into a number of similar fragments, each set of parallel planes of cleavage being equally spaced throughout. For example, cleavage parallel to the faces of a cube leads to cubic fragments; that parallel to the faces of a hexagonal prism to fragments which are triangular prisms

[1] *Riflessioni filosofiche dedotte dalle figure de sali*, Bonon. 1688, and *De salibus dissertatio epistolaris*, Venet. 1705.

[2] *Mineralogische Abhandlungen*, Stück I. Göttingen u. Gotha, 1767.

[3] 'Variæ crystallorum formæ a Spato ortæ' in *Nov. Acta Reg. Soc. Sc. Upsal.*, 1773, i., and 'De formis crystallorum' in *Opusc.* Upsala, 1780, ii.

[4] *Essai de Cristallographie*, Paris, 1772. *Cristallographie, ou description des formes propres à tous les corps du règne minéral*, Paris, 1783.

[5] Schönflies, *Krystallsysteme u. Krystallstructur*, p. 5.

(fig. 1). The units thus obtained, which he calls *molécules intégrantes*,[1] belong, he finds, to one of three simple kinds: they are in some cases tetrahedra, in others triangular prisms, in the remaining cases parallelepipeda,[2] and their form is found by observation to be invariable for a given kind of mineral.[3] He considers that if the process in question does not furnish the precise shapes of the actual crystal molecules, it at least pictures to us a representative analysis of crystal structure which is worthy to stand for the actual facts, and enables us to correlate them.[4] A further partitioning of the *molécules intégrantes* is, indeed, suggested, which would assign a definite relative position in space to *the elements* forming a chemical compound,[5] but the chemical atoms (*molécules élémentaires*) of various kinds thus supposed to have distinct places in the crystal substance, and to be of definite and constant form, are not made the subject of investigation. The *molécules intégrantes* are supposed to result from the regular combination of the latter to form a single kind of unit or molecule, and these alone form the basis of Haüy's theory of crystal structure.

Adopting the idea put forward by Romé de l'Isle of the existence in every crystal of a primitive form,[6] or nucleus, Haüy supposes that this nucleus consists of a considerable number of *molécules intégrantes*,[7] and that the primary faces of a crystal are the outcome of regular accretion upon the faces of the nucleus. Secondary crystal faces are those not parallel to the cleavages, and these are explained by supposing that the successive layers deposited on each face of the primary nucleus do not overlap preceding layers sufficiently to yield merely an enlarged figure of the same shape as the nucleus, but, falling short of this in a regular manner, form by their boundaries planes which truncate the edges or corners of the enlarged figure referred to.[8] He points out, however, that since microscopic crystals have as complete a complement of faces as those of larger growth, the modification by which the structure acquires new faces must be an initial one, which takes place once for all, subsequent growth being the result of accretion upon secondary and primary faces alike.[9]

In cases where the *molécules intégrantes* are parallelepipeda this mapping out of secondary face directions by the edges bordering successive layers where the boundaries of added layers fall short at edges or corners in a regular manner, is easy to follow. In order to explain in a similar manner the production of new faces, where the *molécules intégrantes* are tetrahedra or triangular prisms, Haüy regards these molecules as aggregated to form parallelepipedal groups, which he calls *molécules soustractives*.[10] This is, of course, merely a geometrical conception, intended to elucidate the growth of secondary faces by regular decrease in extent of succeeding layers, and does not refer to any physical association of the *molécules intégrantes* to form *molécules soustractives*;

[1] *Traité de Minéralogie*, Paris, 1801, i. pp. xiv and 6. [2] *Ibid.*, p. 30.
[3] *Ibid.*, pp. xiv and 20, 29, and 32. [4] *Ibid.*, pp. 7 and 31. [5] *Ibid.*, p. 6.
[6] *Traité de Minéralogie*, i. pp. 20 and 28, also p. 481. Haüy says in another place: 'La forme primitive paroît être le résultat de la crystallisation la plus parfaite dont un minéral soit susceptible; mais ce n'est pas toujours celle qui se rencontre le plus ordinairement' (*Essai d'une Théorie sur la Structure des Crystaux*, Paris, 1784, p. 50).
[7] *Traité de Minéralogie*, i. p. 29. Thus he considers that the primitive form of tourmaline is a rhombohedron, but that the *molécule intégrante* is a tetrahedron, which is the sixth part of such a rhombohedron (see *ibid.*, p. 30).
[8] *Ibid.*, p. 34 *et seq.*, also p. 285. [9] *Ibid.*, p. 98. [10] *Ibid.*, p. 97.

for the purpose of explaining the production of secondary faces, it enables all the structures formed by the *molécules intégrantes* to be regarded as composed of parallelepipedal units,[1] although these may be only geometrical fictions.

The hexagonal structure of figs. 1 and 2 may be regarded either as built up of the *molécules intégrantes* ABC, which are triangular prisms, or of the *molécules soustractives* ABDC, which are rhombic prisms of 120° and 60°.

The crystal may then be regarded as consisting of *molécules soustractives*, which are parallelepipeda packed together in parallel positions so as to fill space (fig. 4, p. 305).

The growth of the secondary faces by decrements consisting of whole numbers of the *molécules soustractives* leads directly to the great and fundamental Law of the Rationality of Intercepts.[2] (This Law will be referred to below under its more familiar name, the Law of Rational Indices.) The truth of this law Haüy himself established by the measurement of a vast number of crystals, and it seemed to carry with it the justification of his apparently arbitrary theory of their structure.

FIG. 1.

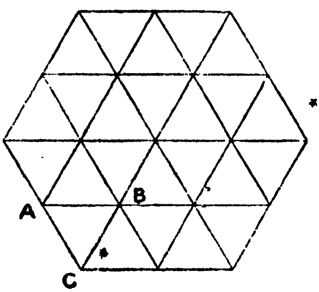
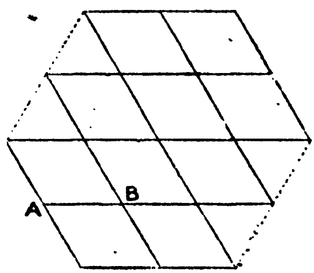


FIG. 2.



It will, however, be found later that an hypothesis of a more general character leads to the same results.

Put concisely, the objections to Haüy's conclusions as to the nature of the ultimate particles of crystals are the following :—

1. Haüy has to suppose that crystal surfaces, apparently plane, are actually corrugated,[3] and, if the same be admitted with regard to cleavage planes, other forms for the *molécules intégrantes* than those which he deduces are possible. It is easy to picture a simple case in which the directions of cleavage would prove a fallacious guide to the determination of the shape of the ultimate units of a body.

Thus suppose that a number of equal regular hexagonal prisms of some uniform material are fastened together in a close and regular manner by a uniform but weak cement, so that the adhesion between the prisms is much weaker than the cohesion of their substance. It is, then, evident

[1] *Traité de Minéralogie*, pp. 97 and 284. Comp. Bravais' conceptions (see below, p. 306).

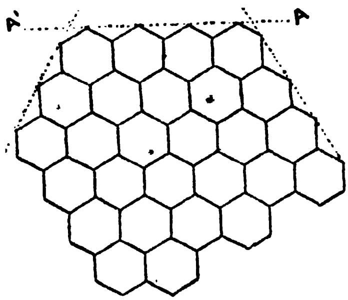
[2] This law carries with it the exclusion of two of the five regular polyhedra from the forms possible for crystals, *i.e.*, of the regular pentagonal dodecahedron and the icosahedron (*ibid.*, p. 80).

[3] See his explanation of the occurrence of secondary faces just referred to above.

that they will most readily separate along zigzag surfaces whose *mean* transverse direction is that of normals to prism faces, *e.g.*, AA′ in fig. 3; and, neglecting the corrugation of these cleavage surfaces, we have three cleavage directions AA′, BB′, CC′, making angles of 60° with each other. Thus the hexagonal cleavage would result from a structure consisting of hexagonal prisms just as well as from one consisting of triangular prisms. The fact that most of the units which Haüy obtains, whether *molécules intégrantes* or *molécules soustractives*, display holohedral symmetry shows that there is room for some wider conception as to the ultimate nature of the cleavage surfaces.

2. Some of the figures to which cleavage leads are neither parallelepipeda which can be packed together as *molécules soustractives,* nor other figures which can be packed together as *molécules intégrantes.* The octahedral cleavage of fluor spar, for example, leads either to octahedra or tetrahedra not fitting closely together, but with spaces between them. This incompatibility of the results of the partitioning with the conception of uniform divisibility into identical plane-faced molecules indicates that

FIG. 3.



the *molécules intégrantes* as well as the *molécules soustractives* are mere geometrical abstractions; indeed, such probably was the view of Haüy himself.

3. Haüy's method is not of universal application, since in some crystals no cleavage planes are discoverable. In such cases supplementary hypotheses become requisite.[1]

Cleavage is, then, an uncertain guide to the determination of the form of the ultimate particles of crystals. Nevertheless, cleavage led to the discovery of the law of rational indices, and the conception of parallelepipedal units built up into a crystalline structure furnishes at any rate an explanation of this law, and is in accordance with most of the properties of crystals, whether it be derived from cleavage or not. Haüy's *molécules intégrantes* are even more suggestive, in the light of subsequent research, than his *molécules soustractives,* since they reduce the problem of crystal structure to a problem of partitioning space into similar polyhedra which are not necessarily parallel. For example, the arrangement of triangular prisms of fig. 1, which is suggested by cleavage parallel to the faces of an

[1] Haüy, *Traité de Minéralogie*, i. p. 27.

hexagonal prism, contains two sets of prisms differently orientated. This case will be alluded to again (see p. 327).

The Space-lattice.

We next come upon investigations based on Haüy's conclusions derived from cleavage, but widely differing in essential character from them, in which this property is found to take quite a subordinate place, and is treated merely as evidence of internal symmetry, the question of the shape of the ultimate units having sunk into insignificance. We find, indeed, that while Haüy's discovery of the law of rational indices proved to be an epoch-making one, his suggestions as to the nature of the ultimate particles, based on cleavage, came very soon to be treated as merely diagrammatic, and as expressing more than is justified by the experimental facts.

Without following Haüy in his speculations and arguments, or striking out any new path of deduction for themselves, Weiss[1] and Mohs[2] by their well known method placed in a far clearer light the ascertained facts, not only those respecting outward form, but also the optical facts relating to double refraction. By this time the occurrence of many new varieties of symmetry had been recognised both on morphological and on physical evidence; in particular the existence of the monosymmetric system had been established, and attempts were being made to classify the varieties of crystal forms according to their symmetry.

To this period belongs the remarkable work of Hessel,[3] an investigation which, though published in 1830, remained overlooked until the year 1891, when it was unearthed by Sohncke.[4]

Hessel considered the general question of the possible symmetry of solid plane-faced figures, and then, by imposing the limitation that these figures should obey Haüy's law of rational indices, deduced the result that only thirty-two types of symmetry are possible for crystals. This achievement is all the more surprising since, at the time when Hessel wrote, comparatively few of these thirty-two types had been discovered in nature. The same important result was independently rediscovered by Gadolin (1867), to whose methods reference will presently be made.[5]

In the previous year (1866) Viktor von Lang, in his treatise on crystallography,[6] had very clearly laid down the principles of crystal

[1] 'De indagando formarum crystallinarum charactere geometrico principali dissertatio.' Lipsiæ, 1809. 'Uebersichtliche Darstellung der verschiedenen natürlichen Abtheilungen der Krystallisationssysteme' (*Abhandl. d. Berl. Ak. d. Wissenschaft*, Phys. Klasse, 1814–15, pp. 289–336).

[2] 'The characters of the classes, orders, genera, and species; or, the characteristics of the Natural History System of Mineralogy,' Edinburgh, 1820. Treatise on Mineralogy; or the Natural History of the Mineral Kingdom (translated from the German), Edinburgh, 1825.

[3] Article 'Krystall' in Gehler's *Physikal. Wörterbuch*, 1830, v. 1023–1340. Also 'Krystallometrie oder Krystallonomie und Krystallographie.' Leipzig, 1831, and reprinted in 2 vols. in Ostwald's *Klass. d. exakt. Wiss.*, 1897, Nos. 88 and 89.

[4] 'Die Entdeckung des Eintheilungsprincips der Krystalle durch J. F. C. Hessel,' *Zeits. für Kryst. Min.*, 1890, xviii. 486. Comp Groth's translation of Gadolin's work on the same subject, Ostwald's *Klass. d. exakten Wiss.*, No. 75, p. 86.

[5] See below, p. 309.

[6] *Lehrbuch der Krystallographie*, Wien, 1866. Thirty years later he shows that these classes may be obtained on the principles established in this work. *Sitzungsb. Ak. Wien*, 1896, cv., II a, p. 362, and *Ann. Phys. Chem.*, 1896, lviii. pp. 710–724.

symmetry, and supplied a method by which the thirty-two classes might have been deduced.

About the time of Hessel's discovery an important change of method was introduced by Seeber,[1] who did not, like Haüy, consider the form of the constituent particles, but confined his attention to the relative situations of *the centres of these particles.* According to him the molecules, which he supposes always to be arranged to form a parallelepipedal network, are separated from each other by intervening spaces. Much the same ideas were shortly afterwards put forward by Delafosse,[2] who, like Seeber, regarded crystals as consisting of molecules regularly arranged in this manner, but not in contact. The following quotation shows that the latter uses the property of cleavage merely as an evidence of the existence of uniform internal symmetry :—

'Indeed, from the possibility of a cleavage in one particular plane direction, we can only conclude that the molecules of the crystal, considered as material points, are distributed on a series of parallel planes; if there are two more cleavages in two new directions we deduce, as a probable consequence, that the molecules must be situated in a uniform and symmetrical manner, having their centres of gravity at the points of intersection of these series of parallel planes, and thus present . . . the picture of a lattice with parallel figured meshes. The molecules make up, in different directions, rectilinear and parallel threads, in each of which their centres of gravity are equidistant. Those threads on the same plane are at equal distances from one another. . . . What Haüy considers as the dimensions of this hypothetical molecule are nothing more than the intervals which separate the real molecules in the directions of the edges or axes of the primitive form.'[3]

Wollaston[4] while, like Hooke, suggesting the presence of spherical molecules, had already remarked that, in place of the spheres, mathematical points endowed with forces of attraction and repulsion can be postulated; Brewster,[5] Dana,[6] and Forster[7] employed very similar conceptions.

We see, then, that while speculations as to the forms of the ultimate particles are soon lost sight of, the geometrical idea which survives and is held in common by various investigators is that *crystal structure consists in the similar repetition throughout space of identical units without regard to their shape or constitution.* The question of the form of the ultimate units of crystals, however interesting, has no essential place in a general investigation which seeks to discover the various ways in which ultimate parts may be uniformly repeated, *i.e.*, an inquiry into the various types of homogeneous structure. The purely geometrical investigation is one which takes no account of the nature of the physical and chemical characters of crystals, but nevertheless it is one of the greatest importance even from the physical and chemical point of view, as will be seen subsequently.

[1] 'Versuch einer Erklärung des innern Baues der festen Körper' in Gilbert's *Annalen der Physik*, 1824, lxxvi. pp. 229–248.

[2] 'Recherches sur la cristallisation considérée sous les rapports physiques et mathématiques,' *Mém. présentées par divers savants à l'Académ. Roy. de Scienc. de l'Inst. de France*, 1843, viii. pp. 641–690.

[3] *Ibid.*, p 649.

[4] *Phil. Trans.*, 1813, pp. 51–63. [5] *Ibid.*, 1830, pp. 87–95.

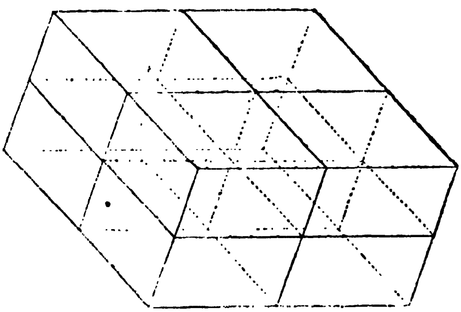
[6] Silliman's *American Journal*, 1836, Series 1, xxx. pp. 275, 296.

[7] *Phil. Mag.*, 1855, Series 4, x. pp. 108–115.

The general problem of the symmetrical space arrangements available for crystals was at first supposed to be a comparatively simple one. Sohncke remarks[1] that all the various extensions of Haüy's theory put forward by the writers above referred to led to the same conclusion, viz., that the arrangement of the middle points of the crystal elements is that of a parallelepipedal network or 'space-lattice' (Raumgitter),[2] such as that shown in fig. 4.

In this simple guise the problem was dealt with exhaustively by M. L. Frankenheim, who investigated the different kinds of parallelepipedal networks of points (Raumgitter) possible in order to ascertain whether these correspond to the various types of symmetry presented by crystals.[3] He did not, however, at first furnish any rigid proof, and his classification of the various kinds of symmetry presented is not perfectly satisfactory: he described fifteen forms as distinct from each other, whereas in fact there are but fourteen, as was afterwards shown by Bravais. He states explicitly that the inquiry is founded solely on the symmetrical arrangement in space of the ultimate particles, and is not based on considerations of the magnitude or the shape of these particles, be they

FIG. 4.



plane-faced like small crystals or rounded; solid spheres or hollow compressible shells; or, indeed, mere centres of force. For the purpose of comparison with the fifteen geometrical systems of points which he has discriminated he classifies crystals into fifteen systems by taking note of *differences in cleavage direction* as well as of differences of crystal form.

The obvious objection to Frankenheim's treatment of the subject is that unless some appropriate configuration be attributed to the particles—and this he expressly disclaims—no hemihedral or hemimorphous forms are accounted for; and yet, as pointed out by Delafosse, there is no more justification for regarding these forms as subsidiary than for so regarding the holohedral forms.

But none the less the solution of the problem of the possible varieties of space lattices, and the establishment of the fact that in their symmetry they correspond to the systems of crystals, marks a very important advance in the theory of crystal structure.

[1] Sohncke, *Entwickelung einer Theorie der Krystallstruktur*, p. 17.
[2] See above, p. 304.
[3] *Die Lehre von der Cohäsion*, Breslau, 1835; also 'System der Crystalle' in *Nova Acta Acad. Cæs. Leopoldino-Carolinæ Nat. Cur.*, 1842, xix. (2), pp. 471–660.

Bravais.

A few years later, Frankenheim's geometrical investigation was supplied with rigid proofs the elegance and clearness of which have excited much admiration. These proofs were the work of Auguste Bravais,[1] who, moreover, enlarged the scope of the inquiry, and, not confining himself to ascertaining the possible varieties of parallelepipedal arrangement of the centres of the ultimate units, proceeded to determine the further varieties of symmetry which can be discriminated by taking into account the individual symmetry of these units, *i.e.*, of the hypothetical atomic groupings to which attention had previously been directed by Delafosse. His work constitutes the first attempt to make a rigid exhaustive investigation of all the different types or varieties of symmetry obtainable by arranging similar bodies or units in space, in a perfectly uniform manner in every possible way.

Basing his arguments on the homologous nature of parallel lines in a crystal, and the consequent possibility of distinguishing in it space-units which are all alike and all similarly situated, *and similarly orientated*,[2] Bravais, like Haüy, regards every crystal as made up of similar polyhedral units or molecules[3] thus placed, and puts forward what purports to be a perfectly general treatment of the subject, independent of any hypothesis as to the actual nature of the polyhedral units. He makes, however, the necessary assumption that these units have a sufficiently symmetrical shape or configuration to be compatible with the general symmetry of the system which they constitute. For example, tetrahedral particles placed to form a cubical space-lattice and appropriately orientated will present a type of symmetry belonging to the regular system, but particles whose figure is a hexagonal prism cannot be thus arranged to belong to this system. As a secondary matter, adopting the suggestion of Delafosse, he regards each polyhedron as an actual crystal molecule made up of constituent atoms. It may be noted that this supposition implies a more intimate relation between the homologous parts of the same unit (*polyèdre*) than subsists between the homologous parts of contiguous units, whereas Haüy's theory only really requires that the mass shall be *geometrically* divisible into similar and similarly orientated units (*molécules soustractives*) which may or may not be physical molecules. In fig. 2, for example, the cell ABCD may represent a molecule, or the molecules may be supposed to be situated at the points A, B, C, D.

Bravais then discriminates between the symmetry due to the arrangement of the centres in a set of similar bodies, or crystal molecules, having a uniform disposition and orientation, and the individual symmetry of the bodies or molecules, and traces the influence of the latter on the symmetry of the assemblage. Thus he discusses separately :—

1. The variety of types of homogeneous 'assemblages' possible, an assemblage consisting of mathematical points each of which is surrounded identically by the assemblage as a whole supposed infinitely extended, and this identity extending to the relative orientation.[4]

[1] Bravais' first step was to consider the regular disposition of similar points on a plane, an inquiry to which he was led by observing the regular arrangement of similar parts in plants (*Compt. Rend.*, 1848, xxvii. pp. 601–604).

[2] 'Mémoire sur les systèmes formés par des points distribués régulièrement sur un plan ou dans l'espace,' *Journ. de l'École Polytech.*, Paris, 1850, xix. p. 127; also 'Études Cristallographiques,' *Journ. de l'École Polytech.*, Paris, 1851, xx. pp. 102 and 97.

[3] Corresponding to the *molécules soustractives* of Haüy.

[4] *Cf.* p. 310.

The assemblage of Bravais is therefore clearly identical with the parallelepipedal network of points already referred to, which had been investigated by Frankenheim.[1]

2. The modifications of these types of symmetry which are introduced by employing, in place of the points, symmetrical figures (*polyèdres*) possessing a symmetry less than that of the parallelepipedal network,[2] though compatible with it—*e.g.*, by forming a *cubic* network of *tetrahedral* particles similarly and appropriately orientated.

Thus in following Bravais' arguments with regard to assemblages we note that, as a rule, he ignores for the moment any modifying or destructive effect exerted by the shape of the units (*polyèdres*) on the elements of symmetry.[3] He first treats a system as consisting only of the *centres* of the units, and after the elements of symmetry of the system thus regarded have been established, he considers the effect of the *shape* of the units;[4] this comes out in his definition of 'faces de même espèce.' He says: 'We will distinguish by the term, faces of the same kind, as we have done in the theory of assemblages, those which can be brought into coincidence, row on row, by a suitable rotation or translation, the coincidence of the faces including with it that of the assemblages. If, moreover, the coincidence includes also that of the molecular polyhedra which may be supposed to lie on the planes of those faces and to participate in their movements, we may say that the faces are of the same kind, and, moreover, identical.'[5] The bodies employed as units have in every case uniform orientation and one which is as symmetrical as possible.

As to the number of kinds of symmetrical arrangement possible included under the first head, he says: 'The degree of symmetry of an assemblage is characterised by the number of the axes of symmetry which it possesses, the order of the symmetry of these axes and their relative situation.'[6] As stated above, he distinguishes fourteen forms, and assigns these to seven classes or systems, according to the number and nature of the axes of symmetry which pass through a given node (*nœud*) or point of the space-lattice.[7] The anorthic space-lattice of fig. 4 possesses only centro-symmetry; if its angles were all right angles it would possess the symmetry of the ortho-rhombic system; if, in addition, its edges were equal it would be a cubic lattice. The similar bodies are called by Bravais in his later work polyhedra (*polyèdres*); in his earlier work on point-systems he speaks of them as summits (*sommets*), and suggests that for convenience of thought they be regarded as having some small dimensions. Their size and shape are, however, in this work generally kept in abeyance, although, before concluding, he refers to the important effects of their shape or composite structure in producing hemihedral and other partial forms.[8] Indeed, according to Bravais' view, the symmetry of the assemblage is actually determined by that of the molecule or unit.[9]

[1] *Études Cristallographiques*, p. 103. [2] *Ibid.*, p. 104. [3] *Ibid.*, p. 103.

[4] This method has been pushed to its extreme by Wulff and Blasius. Comp. Schönflies, *Krystallsysteme u. Krystallstructur*, p. 320.

[5] *Études Cristallographiques*, p. 106. [6] *Ibid.*, p. 104.

[7] *Compt. Rend.*, 1849, xxix p. 135.

[8] *Ibid.*, 1848, xxvii. p. 603. Comp. *Journ. de l'École Polytechnique*, 1850, xix. p. 127; and *Études Cristallographiques*, p. 103.

[9] *Études Cristallographiques*, p. 202.

The definite character of the arrangement of the parts in the individual unit he expresses thus: 'The *geometrical arrangement* of the constituent atoms is the same round the centre of gravity of each molecule.' He adds: 'This last hypothesis is necessary for the explanation of the phenomena of isomerism.'[1] As a result of the rigidity, or fixed relationship, which Bravais attributes to the parts of his molecule, the arranging process of crystallisation is regarded by him as partly consisting in the rotation of the molecules in such a way as to bring about their uniform orientation.[2]

In his study of homogeneous assemblages of points Bravais used the mathematical conception of a coincidence movement (the *Deckbewegung* of German authors), which is now so universally employed in studying the symmetry of a system of points. He supposes each point of a plane of points to consist of two which coincide, and then regards one set of points as movable, the other set as fixed. A movement of the former set which brings it to coincidence with the latter, point by point, but which shifts the position of some or all of the movable points, is a coincidence movement.[3] His method practically consists of a study of the possible varieties of axes of symmetry and the possible ways in which they can exist in a system whose various parts can be derived from each other by movements of translation.

The parallelepipedal nature of the assemblage results from the fact that it possesses movements of translation as one sort of coincidence movements; the classification of assemblages according to their symmetry is effected by considering the various ways in which their parts may be derived from each other by a second sort of coincidence movement—rotation about axes of two-, three-, four-, or six-fold symmetry, which alone are possible in such an assemblage.

The most general form of coincidence movement is a screw spiral,[4] but such a movement is not employed by Bravais, and, indeed, had not been introduced at this period.

Bravais,[5] like Haüy, Delafosse, and Frankenheim, attempts to make cleavage throw light on the nature of the internal symmetry prevailing in certain crystals,[6] and thus to assign particular crystals to a precise type of internal symmetry. Having proved that in the space-lattice some planes of points are more densely packed with points than others, and are at the same time more widely separated from the adjacent parallel planes, Bravais shows how the relative density of the planes may be calculated. He then suggests that there is a connection between the relative density of aggregation of the centres in the different planes drawn in various directions, and the predisposition manifested in crystals to select certain plane directions for their boundaries.

A purely mathematical investigation in taking account of *all* possible types of internal symmetry naturally does not indicate why one type should be more prevalent than another. To determine this point is difficult; indeed, it will probably be impossible till the types of internal

[1] *Études Cristallographiques*, p. 101. For a suggestion that the poles of force to which polarity is due are the constituent atoms definitely placed with respect to one another see *ibid.*, p. 194. [2] *Ibid.*, p. 197.

[3] *Journ. de l'École Polytechnique*, 1850, xix. pp. 3, 26, 32, 57, 98. *Cf.* Sohncke's definition of 'Deckung' in *Entwickelung einer Theorie der Krystallstructur*, p. 28.

[4] See below, p. 311.

[5] *Études Cristallographiques*, p. 202. [6] *Ibid.*, p. 167.

symmetry to which particular crystals belong can be ascertained with more certainty than at present. Some generalisations on the subject were, however, put forward by Bravais,[1] which, though evidently not intended to form part of his rigid argument, being indeed little more than speculation, are interesting and suggestive. Thus he says: 'We can imagine from what precedes how the structure of the molecular polyhedron reacts on that of the crystal and determines the choice of the system . . . we may conclude that the molecular polyhedron is symmetrical, and that its elements of symmetry, tending to pass to the corresponding assemblage, determine the structure of it.'[2]

With Bravais' exhaustive study of the properties of the space-lattice a very important chapter in the history of the theories of crystal structure is closed. Those who hold that the æolotropic homogeneity and symmetry of a crystal are only to be accounted for by a uniform distribution of sameway-orientated molecules or molecular groups must always take their stand upon the work of Bravais. Further, the knowledge of the properties of the space-lattice first provides a single principle capable of explaining at the same time the law of rational indices, the homogeneity of a crystal and the main features of crystalline symmetry; for not only are the fourteen lattices all homogeneous, and their planes a system of crystalline planes, but each of them presents the symmetry characteristic of one of the crystal systems.

It must, however, be remarked that systems of symmetrical repetition exist which obey the law of rational indices, and are therefore possible for crystals, but to whose elucidation the method of Bravais does not apply. One of these systems is described later (p. 314, fig. 5), and, as will be seen, some of his conclusions are inapplicable to types of this nature.

The name of Axel Gadolin[3] is pre-eminently associated with the very important work of deducing the existence of thirty-two types of crystal symmetry from the law of rational indices alone, although, as already remarked, the discovery of these types had been achieved by Hessel many years before.[4] The arguments used by Gadolin, and, indeed, those of Hessel also, purport to deal only with the external form, and thus their bearing on crystal structure is not direct. Nevertheless the great importance of the work in question as corroborative evidence of the existence of a molecular structure will be perceived when it is seen, as will be shown presently, that, whatever view be held with regard to the structure of a crystal, the space-lattice, and therefore also the rationality of indices, must form the basis of the structure; indeed, the discovery of the latter was the immediate outcome of Haüy's concept of a uniformly repeated molecular structure in crystals. Gadolin himself points out that his proof fails to be quite general on account of a certain peculiar case of pseudo-trigonal symmetry,[5] which has subsequently been the subject of much discussion.[6] It has been held that for this reason we are driven to base the

[1] *Études Cristallographiques*, p. 203. [2] *Ibid.*, pp. 203, 204.

[3] 'Mémoire sur la déduction d'un seul principe de tous les systèmes cristallographiques avec leur subdivisions,' *Acta Soc. Scient. Fennicæ*, 1867, vol. ix. pp. 1–71, and separately, Helsingfors, 1871, translated by Groth in Ostwald's *Klassiker der exakten Wissenschaften*, No. 75.

[4] See above, p. 303. [5] 'Mémoire sur la déduction,' &c., p. 50.

[6] Hecht, *Nachr. d. K. Ges. d. Wiss. Göttingen*, 1892, pp. 239–247; *Neues Jahrb.*, 1895 (2), pp. 248–252; Fedorow, *Zeits. Kryst. Min.*, 1895, vol. xxiv. pp. 244 and 607

deduction of the thirty-two classes directly on the existence of a homogeneous molecular structure and not upon morphological considerations alone. Yet it must be confessed that the various possible types of crystal symmetry were clearly and completely laid down by the morphologists without any further speculation regarding structure than is necessitated by Haüy's law, and that every successive advance in the structure theories has been guided or corrected by the knowledge so obtained.

The Principle of Symmetrical Repetition in Space.

Shortly after the publication by Bravais of his elaborate and elegant work, a new departure was made in the elucidation of homogeneity of structure, the importance of which can scarcely be overrated.

The first step was taken by Chr. Wiener,[1] who laid down the principle that regularity in the arrangement of identical atoms is presented when every atom has the remaining atoms arranged about it in the same manner;[2] thus making homogeneity depend primarily on the continual repetition throughout space of the same relation between an element and the entire structure, regarded as unlimited, instead of laying stress on sameway orientation.[3] The principle adopted by Wiener, when employed in all its generality, leads to an adequate classification, according to their symmetry, of all cases of identical repetition throughout space whatever.[4]

The possibility of partitioning a homogeneous structure into similar sameway-orientated parts whose centres form a parallelepipedal lattice[5] must always be the important property which enables us to trace to its source Haüy's great law of the rationality of indices; but this possibility is only a collateral fact when Wiener's principle is discussed; indeed, the carrying out of such a partitioning, while always possible,[6] often complicates instead of simplifying matters so far as the symmetry is concerned.[7] The problem to be solved, presented in its most general form, is not even to find under what conditions the separation of the structure into similar composite units of any sort can take place, but simply the analysis of the nature of the repetition in space of the similar parts.

Jordan.

Although Wiener made some interesting applications of his principle and described several kinds of symmetrical repetition in space which are examples of it, he did not deal with the subject exhaustively; the solution of the general problem was effected by Camille Jordan in a memoir the title of which contains no reference to homogeneity or to crystals.[8] This mathematician has furnished a perfectly general method of defining the regular repetition in space of identical parts, and has shown that the typical cases of such repetition are limited in number. He points out that, when

Viola, *ibid.*, 1896, vol. xxvi. p. 128, and 1897, xxvii. pp. 399–405; De Souza-Brandão, *Zeits. Kryst. Min.*, 1894, vol. xxiii. pp. 249–258, and 1897, vol. xxvii. pp. 545–555; Barlow, *Phil. Mag.*, 1901, series 6, vol. i. p. 3.

[1] *Die Grundzüge der Weltordnung*, Leipzig and Heidelberg, 1869.

[2] 'Die Regelmässigkeit findet dann statt, wenn jedes Atom die anderen Atome in übereinstimmender Weise um sich gestellt hat,' *ibid.*, p. 82.

[3] Cf. *Min. Mag.*, 1896, vol. xi. p. 119

[4] See below, p. 321.

[5] Sohncke's *Entwickelung einer Theorie der Krystallstruktur*, p. 207.

[6] *Krystallsysteme und Krystallstructur*, p. 360. Comp. *Phil. Mag.*, 1901, series 6, vol. i. p. 19.

[7] Comp. *Min. Mag.*, 1896, vol. xi. p. 125.

[8] 'Mémoire sur les Groupes de Mouvements.' *Annali di matematica pura ed applicata*, Milano, 1869, series 2, vol. ii. pp. 167 215, 322–345.

identical repetition of its parts is exhibited by any mechanical or geometrical rigid system, this system being, in some of the cases, supposed infinitely extended in every direction, a certain definite series or group of correlated movements may be employed, each term of which is a movement of such a nature that, while the system is actually shifted by it, the appearance after the movement has taken place is absolutely unchanged, every point moved being caused to travel to the place previously occupied by some homologous point.[1] The fundamental condition that such a group of movements may exist is that homologous parts everywhere bear an identical relation to the system as a whole; the members of the group are so related that every individual movement may be regarded as the resultant of some two or more movements also belonging to the group.[2]

While it is always found possible to partition any system of this kind, in which the repetitions are continually repeated in every direction, in such a way that the units obtained are all alike and *sameway-orientated, as in Bravais' systems*,[3] the latter property is, as has been said, but a secondary one, and not of the nature of a definition, the condition stated above constituting a definition complete in itself. A homogeneous structure can thus be classed according to the type of the infinite group of coincidence movements which connect all its homologous parts.

The obvious advantage of this method of dealing with homogeneity is its complete generality—that it requires no further limitation of the nature of the homogeneous structure than that which prescribes the kind of repetition presented by its homologous parts.[4] Thus if molecules of a certain individual symmetry with a relative space-lattice arrangement of some kind are postulated, after the manner of Bravais and others, Jordan's method, unlike Bravais', deals in one process both with the symmetry of the individual, so far as this affects the general symmetry, and also with the symmetry of arrangement. All possible molecular theories of crystals can alike be subjected to Jordan's method, and it is independent of them all.

The following is the course of Jordan's argument:—After reminding his readers that every movement of a solid body in space can be regarded as a screw-spiral movement, he remarks that such a movement is fully known when we are given—

1. The situation in space of the axis of rotation A, which has also the direction of translation.
2. The angle T, through which the solid is turned about the axis.
3. The longitudinal displacement t, to which the body is subjected in the direction of the axis.

He then observes that the displacement produced by two or more such movements made successively can also be produced by a single screw-spiral movement of some kind; and the resultant of a number of movements successively made can be definitely expressed in the terms just laid down if the expressions for the component movements are known.

Jordan next proceeds to point out that, a few movements being given, it is possible to arrive at all the various movements or displacements

[1] For a definition of a coincidence movement see Sohncke's *Entwickelung einer Theorie der Krystallstruktur*, p. 28, or *Min. Mag.*, 1896, vol. xi. p. 125, note 3. Comp. Schönflies, *Krystallsysteme und Krystallstructur*, p. 54.

[2] Schönflies, *Krystallsysteme und Krystallstructur*, pp. 256 and 359.

[3] See above, p. 306.

[4] *Cf.* Schönflies, *Krystallsysteme und Krystallstructur*, p. 44, par. 2.

obtainable by combining these given movements executed successively any number of times in any order whatever. Of *groups* of movements arrived at in this way, some are of a finite character, and some contain movements infinitely small; the remaining kind—those which consist of movements whose loci extend infinitely throughout space in every direction, and which are none of them infinitely small as compared with the others—comprise, as was subsequently perceived,[1] all those that are available for the production or definition of homogeneous structures which display the symmetry of crystals.[2]

The movements belonging to an infinite group of movements, like any individual movement, can be completely defined by reference to certain axes of rotation and directions of translation; but for the sake of perspicuity it is desirable to place a number of similar particles or bodies in all the positions, throughout some considerable space, to which one of them would be moved by the various movements constituting the group. When this is done the kind of symmetry presented by the system formed of the group of movements can be readily perceived,[3] and at the same time the nature of the parts repeated can be left an open question.

If it be desired by the crystallographer to find in a given homogeneous system a complete set of identical planes by means of the group of movements proper to the system, the following course may be adopted.

Take three points—A, B, C—whose identical relation to the system is such that the aspect of the unlimited structure is the same *and presents the same orientation* viewed from each of them, and let their distances apart be not great as compared with the minimum distances separating homologous parts of the structure. The repeated carrying out of the three translations—AB, BC, CA in both directions—will locate an infinitude of points lying in the plane of the three points, and all having precisely the same relation to the structure as that presented for the latter. This plane may therefore be designated *a homogeneous plane*,[4] and since the translations of the structure are not infinitesimal, it is easy to prove that a plane so situated will obey the law of the rationality of indices when referred to axes which pass through strings of identical points.[5] When such a plane is subjected to the various coincidence-movements constituting the group characteristic of the structure, an infinite set of planes is found, which all have an identical relation to the structure. The number of different orientations presented by the planes is limited.

Sohncke.

The treatment of homogeneity of structure by Jordan's method leads to a classification which discriminates the various types of identical

[1] See below, p. 315. Cf. *Krystallsysteme u. Krystallstructur*, pp. 360 and 636; also see above, note 3, p. 298.

[2] It is interesting to notice that Jordan does not appear to have regarded his work as throwing any fresh light on crystal structure, but treats Bravais' work as complete in this direction. He says: 'M. Bravais has studied this question; the particular cases which he has discussed, and of which he has made a remarkable application to crystallography, are the most important. Nevertheless I believe there is at the present time some interest in treating the problem quite generally.' (*Mémoire sur les Groupes de Mouvements*, p. 168.)

[3] See *Min. Mag.*, 1896, xi. p. 119, and see below, p. 333.

[4] See *Phil. Mag.*, 1901, series 6, i. p. 19.

[5] The hypothesis with regard to crystals is that their faces lie in homogeneous planes. See Bravais, *Études Crystallographiques*, p. 103.

repetition of possible parts, each type having its own characteristic group of coincidence-movements. Jordan, however, left his work incomplete and omitted many of the types, which were subsequently discovered by Sohncke, to whom reference must next be made.

The important bearing of Jordan's work on crystal structure seems to have been entirely overlooked until the publication of the widely influential works of Leonhard Sohncke.[1] This writer, employing Wiener's principle[2] and using Jordan's method to discover what variety of types of symmetry can exist in systems produced by the identical repetition of finite parts or atoms[3] throughout space, obtains what he calls a 'regular point-system,' which he thus defines: 'A regular point-system is one in which the pencils of lines drawn from each point of the system to all the remainder are congruent with each other.'[4] These systems, if classified according to the position and nature of their axes of symmetry (whether screw-axes or axes of rotation), are sixty-five[5] in number. They may conveniently be designated 'Sohncke systems.'

A Sohncke system then consists of a homogeneous assemblage of points symmetrically and identically arranged about axes of symmetry, and these may be screw-axes such that the points surround them in a spiral arrangement. It might at first sight appear that the latter are inconsistent with the law of rational indices. Since, however, among the coincidence-movements of the system the translations and rotations proper to some space-lattice are always present, it may be proved that a Sohncke-system consists in general of two or more congruent space-lattices which interpenetrate. The translation movements of the Sohncke-system are those which are common to the constituent space-lattices.

[1] 'Gruppirung der Moleküle in den Krystallen: eine theoretische Ableitung der Krystallsysteme,' *Pogg. Ann.*, 1867, cxxxii. 75; 'Die unbegr. regelm. Punktsysteme als Grundl. e. Theorie der Krystallstructur,' *Verh. naturw. Ver. Karlsruhe*, 1876 (7); 'Zurückweis. e. Einwurfs geg. d. neue Theor. d. Krystallstruct.,' *Wied. Ann.*, 1879, vi. 545; 'Ableitung d. Grundges. d. Krystallsys. a. d. Theor. d. Krystallstructur,' *ib.*, 1882, xvi. 489. and *Verh. naturw. Ver. Karlsruhe*, 1882 (9); 'Elementares Nachweis einer Eigensch. parallelep. Punktsysteme,' *Zeits. Kryst. Min.*, 1888, xiii. 209; 'Entwickelung einer Theorie der Krystallstruktur,' Leipzig, 1879; 'Übe- Spaltungsflächen und natürliche Krystallflächen,' *Zeits. Kryst. Min.*, 1888, xiii. 214–235; 'Erweiterung der Theorie der Krystalle,' *ib.*, 1888, xiv. 426–446; 'Di- Entdeckung des Eintheilungsprincips der Krystalle durch J. F C. Hessel,' *ib.*, 1890, xviii. 486–498; 'Die Structur der optisch drehenden Krystalle,' *ib.*, 1891, xix. 529-559; 'Die Structur der hemimorph-hemiëdrischen, bezw. tetartoëdrischen drehenden Krystalle,' *ib.*, 1896, xxv. 529–530.

[2] Sohncke, speaking of his own principal treatise, says: 'Man findet hier die ganze Mannigfaltigkeit der überhaupt möglichen Krystalistrukturformen aus einem einzigen Princip, nämlich aus dem selbstverständlichen Grundsatze von der regelmässigen Anordnung, auf streng mathematischem Wege abgeleitet' (*Entwickelung einer Theorie der Krystallstruktur*, Vorwort, p. iii).

[3] *Ib.* p. iii; also p. 26: 'Mit. Benutzung des Grundgedankens der Jordan'schen Methode, aber mit Weglasssung alles dessen, was nicht direkten Bezug zur Krystallstruktur hat, sind nun im Folgenden alle überhaupt möglichen regelmässigen Punktsysteme von unbegrenzter Ausdehnung abgeleitet und somit alle denkbaren Strukturformen krystallisirter Körper ermittelt.' And later, p. 29: '. . . die verschiedenen Arten von Deckbewegungen als Eintheilungsgrund für die regelmässigen Punktsysteme dienen.' He employs some well known kinematic propositions relating to rigid systems to aid him in arriving at his results.

[4] *Ib.*, p. 28.

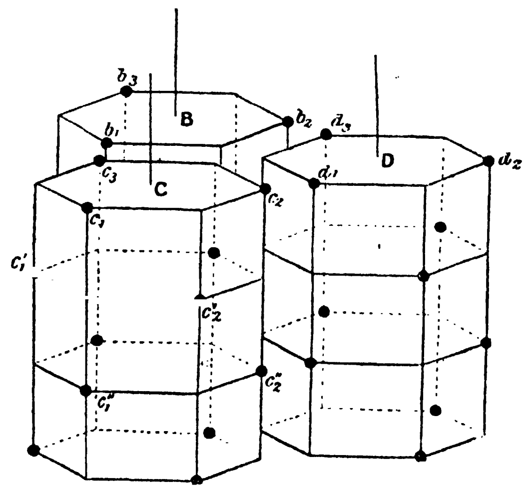
[5] In his principal work, *Die Entwickelung*, &c., Sohncke describes sixty-six types, but subsequently concludes that there are but sixty-five, Nos. 9 and 13 of his systems being the same type. *Zeits. Kryst. Min.*, 1888, vol. xiv. p. 423.

Hence the points of the Sohncke-system may always be grouped together in sets such that the centres of gravity of the sets constitute some space-lattice. The law of rational indices is, therefore, applicable to a Sohncke-system as well as to the space-lattice.

Fig. 5, for example, represents a Sohncke-system of points possessing screw-axes of hexagonal symmetry at B, C, D (No. 46 of Sohncke's treatise). A point is brought into coincidence with a neighbouring point by giving the system a rotation of 60° about one of these axes, accompanied by a translation along the axis.

If every set of six points, such as c_1, c_2, c_3, c_1', c_2', c_3', be regarded as grouped about a single point at their centre of gravity, γ, the Sohncke-system of fig. 5 can be treated as composed of groups of six points whose centres form the space-lattice of fig. 6, in which the points all lie at equal intervals on straight lines.[1] (The lattice of fig. 6, like that of fig. 2, possesses trigonal axes.) The Sohncke-system may therefore be regarded

FIG. 5.



as consisting of six similar lattices constructed from c_1, c_2, c_3, c_1', c_2', c_3'; the planes whose directions are given by any such points as β, γ, δ form a crystalline system of planes which obey the law of rational indices. They may, therefore, be taken to represent the faces of the crystal.

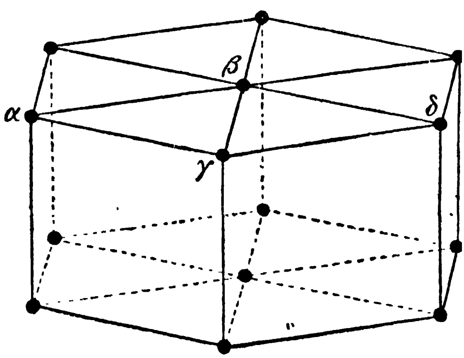
In such systems, and in others to be described below, it must be remembered that the points of the figure may represent merely homologous points in the material of which the crystal consists, whatever may be the nature of that material; it is not necessary to regard them as representing atoms or molecules, or as presupposing anything relating to atoms or molecules.

[1] A lattice formed of points vertically midway between the points of the one figure applies equally well, since the points of the Sohncke-system can just as symmetrically be allotted to form groups having these other points as centres.

Further, it must be noted that the system of coincidence-movements of fig. 5 does not necessarily possess any planes of symmetry. The mere Sohncke-system of points or a system of spheres placed at the points of fig. 5 would possess planes of symmetry, but a parallel system of unsymmetrical pear-shaped bodies would not.

The application of Bravais' method to a system of this kind is inconvenient because it is impossible to partition it into identical same-way orientated units of any kind *without lowering the symmetry by the act of partitioning*. Thus in the case in question an hexagonal axis is impossible for the unit because the hexagonal axes present in the system are none of them mere axes of rotation, and, therefore, the movements about them are incapable of bringing any conceivable unit to coincidence with itself. This renders some important conclusions of Bravais inapplicable to such a system. Thus he argues that in all holohedral crystals the molecular polyhedra possess the same axes and planes of symmetry as the assemblage. Now the system of hexagonal symmetry just described becomes holohedral if it consists of points or spheres lying on planes

FIG. 6.



drawn through the nearest hexagonal axes, and yet, as just remarked, no kind of partitioning can produce in it units having hexagonal axes.

Regarded as an investigation of the total number of ways in which *identical* repetition can take place, and, therefore, as an investigation of the number of types of homogeneous structure so obtainable, Sohncke's work is exhaustive and complete. He begins without any assumption involving knowledge of previous views or methods, and rigidly deduces the total number of types just mentioned.[1] His method, however, is not free from objection, since, in order to account for the thirty-two different classes, he is, like Bravais, driven to make the symmetry of a system depend partly on the arrangement of the ultimate parts or atoms and partly on the configuration of these atoms. He treats the parts repeated

[1] See *ib.*, p. iv.: '. . . ich die ganze Untersuchung, soweit sie auf Krystallographie Bezug hat, selbstständig von vorn anfing, natürlich mit Benutzung des bewährten Grundgedankens der Jordan'schen Methode.'

as points or particles of perfectly regular (spherical) form, or at least ignores their polarity if they have any, and, as a consequence of this supposed regularity of the atoms, he attributes to some of Jordan's systems an additional element of symmetry not *necessarily* involved by their coincidence movements. Thus he regards some of the sixty-five types as necessarily possessing planes of symmetry.[1] When, however, he comes to speak of hemimorphous crystals, *i.e.*, those which are differently terminated at opposite ends of an axis of symmetry, he follows the example of Bravais at least in his earlier writings and resorts to the supplementary hypothesis that the molecules possess polarity.[2]

The problem which Sohncke sets himself to solve is, then, the construction of all kinds of regular *i.e.*, homogeneously arranged [3]—assemblages composed of sets of identical particles, the shape of the particles being ignored, or, in other words, treated as quite regular, *i.e.*, spherical.[4] If he had succeeded in forming on these lines simple assemblages *among which were represented all the thirty-two classes of crystal symmetry*, his work would have been consistent with the supposition that crystals consist in every case of *a single kind* of molecule whose shape and constitution are destitute of polarity, the symmetry of the structure being entirely determined by the relative situations of the molecules. He did not, apparently, at any time hope to completely achieve this, for he admitted the necessity of a supplementary hypothesis to account for hemimorphism ; but, save for the few cases of this property, he appears, in the first instance, to have hoped to reach an adequate theory based solely on the relative position of the molecules, without taking account of their shape.

The insufficiency of Sohncke's earlier theory that the molecules are perfectly regular and *all of one kind, and identically related to the structure as a whole*, was presently pointed out by several writers, among whom may be mentioned Wulff[5] and Haag,[6] the former in particular having called attention to the existence of certain known crystal forms, namely, those possessing the symmetry of the mineral dioptase, which are not found represented among the sixty-five systems.

Sohncke himself subsequently confessed the inadequacy of the theory in question,[7] and was led to enlarge his method. Thus, after reviewing some examples of more generalised point-systems devised by Wollaston, Barlow, and Haag, he suggested the following modified theory :—

Instead of regarding the spherical particles or points composing a homogeneous assemblage as all of one kind, let a limited number of kinds

[1] *Zeits. Kryst. Min.*, 1892, vol. xx. p. 448.

[2] *Entwickelung einer Theorie*, etc., p. 200.

[3] See Wiener's definition of homogeneity in *Grundzüge der Weltordnung*, p. 82 *et seq.* Cf. *Min. Mag.*, 1896, vol. xi. p. 120.

[4] Comp. *Krystallsysteme und Krystallstructur*, pp. 595, 596, and p. 612. Sohncke says (*Zeits. Kryst. Min.*, 1892, vol. xx. p. 452): 'I have always considered the elementary particles to possess only so much symmetry that they do not disturb the symmetry of the point-system.' The effect of this is that, so far as the general symmetry is concerned, they behave as though they were spherical.

[5] 'Ueber die regelmässigen Punktsysteme,' *Zeits. Kryst. Min.*, 1888, vol. xiii. pp. 503-566.

[6] *Die regulären Krystallkörper*, Rothweil, 1887 (see reference in *Zeits. Kryst. Min.*, 1888, vol. xvi. p. 501).

[7] 'Bemerkungen zu Herrn Wulff's Theorie der Krystallstructur,' *Zeits. Kryst. Min.*, vol. xiv. 417. See also 'Erweiterung der Theorie der Krystallstructur,' *ib.*, p. 426.

(1, 2, 3, or *n*) be present, the component assemblage formed by each kind, taken by itself, being homogeneously arranged, and all the different kinds possessing identical systems of axes and having the same set of translations common to them.[1]

Sohncke's aim is, as has been said, to produce the requisite varieties of symmetry by arranging *regular or spherical* particles homogeneously. This he succeeds in doing by his enlarged method, and is now able to cover the cases of hemimorphism.[2] Instead, however, of merely stipulating that the component point-systems shall have the same *translations* common to them, and possess identical systems of axes, he ought to have stipulated that they shall have *all their coincidence-movements* in common.[3]

For all the coincidence-movements which characterise the combined system as a whole must obviously be obeyed by every particle within it, and it is only these movements which really belong to the component-systems *as found in the structure*. In other words, if there are other coincidence-movements in addition to these, which a set of points would have *if taken alone*, such movements must for the combined system be regarded as non-existent, and *only those points of such a set will have identical positions in the entire system which can be brought to coincidence by the surviving movements*, *i.e.*, by those which characterise the structure as a whole. After making this distinction it will usually be possible to detect two or more different kinds of points forming two or more different subsidiary point-systems, which must be counted separately, as many systems being discriminated as there are varieties of position of the points. When this is done the various different point-systems present will have all their coincidence-movements in common, these movements being those characteristic of the combined system as a whole.

Reference to an example may make this clearer to those who are familiar with Sohncke's treatise. Let two point-systems (*a* and *b*) be taken, each of which, when regarded apart from the other, presents the same instance of type No. 2 of Sohncke, and which have their systems of axes and their translations identical; let them be combined in such a way that they are sameway orientated and have the two sets of points lying in the same planes, but with the axes distinct. See fig. 7, in which, to distinguish the two systems, one (*b*) is represented in dotted lines. Either system consists of a series of equidistant parallel planes, each beset with particles in the same way; and the diagram is one such plane; the points in the succeeding planes lie vertically below those in the diagram. Then the combination thus formed must be regarded as consisting of four separate point-systems, not of two only, for the positions in the composite structure occupied by the points are of four different kinds. Each of the four sets is destitute of axes; the composite system has merely the symmetry which it would have had if constructed of four distinct point-systems, each possessing the translations common to the two initial systems, and consisting of points lying in the same planes.

In Sohncke's work rigid geometrical results are closely interwoven

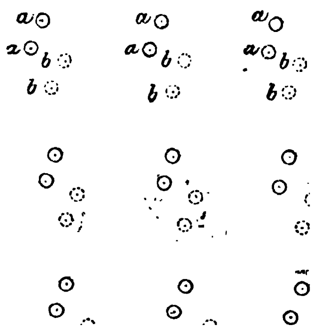
[1] *Zeits. Kryst. Min.*, 1888, vol. xiv. p. 433. Comp. *ib.*, 1892, vol. xx. p. 456.

[2] For further applications of his method see 'Zwei Theorien der Krystallstructur,' *Zeits. Kryst. Min.*, 1892, vol. xx. p. 455.

[3] Sohncke was disposed at first to make this stipulation, but did not perceive its necessity; he afterwards definitely adopted the less precise one to which objection is here taken. Comp. *Zeits. Kryst. Min.*, 1888, vol. xiv. p. 441, and 1892, vol. xx. p. 456.

with theoretical considerations relating to systems of regular particles, and the very title of his principal treatise, 'Entwickelung einer Theorie der Krystallstruktur,' shows that he addresses himself rather to establishing a physical theory than to the demonstration of a set of purely geometrical propositions. From the geometrical point of view, his investigation constitutes, as has been said, a completion of Camille Jordan's work, already referred to: he has traced the symmetrical features of the various infinite groups of movements described by the latter, and has discovered a number of additional groups which Jordan had overlooked;[1] so far his work is indisputably a mathematical demonstration, not a plausible theory. Jordan's groups of movements constitute purely geometrical configurations, and their symmetrical features are perfectly definite and traceable *without postulating the nature of the structure which repeats itself throughout space*; it is not essential to the geometrical reasoning that this structure shall consist of a Sohnckian assemblage of

FIG. 7.



discrete particles separated by void spaces;[2] its constitution may indeed remain quite undefined, so long as it is capable of the requisite coincidence-movements.

With Sohncke, however, the crystal element is not devoid of a certain hypothetical character, as is shown by his employment of an arbitrary fundamental proposition (*Grundsatz*).[3] This asserts that the symmetry displayed by a crystal cannot be lower than that of the point-system, according to which the centres of its elementary particles (*Krystallbausteine*) are arranged. Evidently the effect of such a provision is to insist on the regularity of form of these elementary particles or to treat their shape as a negligible factor. As Sohncke contends that this provision is a physical, not a geometrical, necessity it is obvious that his particles are not mere geometrical space units; indeed it is always possible so to

[1] *Entwickelung einer Theorie der Krystallstruktur*, p. 26.

[2] The plausibility of the conception of discrete particles or centres of force is generally admitted; the point here insisted on is that this conception is not essential to the geometrical reasoning under review. See *Min. Mag.*, 1896, vol. xi. p. 120. Comp. *Krystallsysteme und Krystallstructur*, p. 237.

[3] *Zeits. Kryst. Min.*, 1892, vol. xx. p. 447.

partition a homogeneous structure geometrically into identical units that the symmetry of the system shall be determined solely by the arrangement of the units, and not at all by their shape,[1] and therefore, as applied to such units, Sohncke's fundamental proposition would be universally true, not, as he puts it, a limitation (*Beschränkung*).[2]

Sohncke states the aim of his investigation in these words: 'I might rather regard this aim to be the evolution from the simplest and most evident axioms by logical methods such conceptions as to the building up of crystals from their molecules as are in strict agreement with observed facts, and may, therefore, be regarded as natural.'[3]

He adds the remark that the non-acceptance of his fundamental proposition and his conclusions is justifiable if they are held to be improbable. This is not language which would be appropriate to pure geometry.

Mirror-Image Repetition.

We now come to a very important departure in the investigation of crystal structure. Jordan's conception of infinite groups of movements leads, as we have seen, to identical repetition of parts extending throughout space. It has been pointed out that it is possible to draw in each of these groups, or in the systems formed by their means, sets of planes identically related to the group or system regarded as an infinite whole; hereby is provided a purely geometrical method of defining homogeneity of structure in a perfectly general manner, which would be of interest to mathematicians if no such body as a crystal existed; but, further, the laws of symmetry which govern the relative arrangement of the identically corresponding plane-directions present in a homogeneous structure are also established. Crystals, however, display not only identity of parts,

[1] See *Phil. Mag.*, series 6, 1901, vol. i. p. 7.

[2] *Zeits. Kryst. Min.*, 1892, vol. xx. p. 448; cf. *Min. Mag.*, 1896, vol. xi. p. 125; also Schönflies, *Krystallsysteme und Krystallstructur*, p. 616.

That Sohncke regards the crystal elements whose centres furnish the points of

crystal. Thus he says (p. 27 of his *Entwickelung einer Theorie*, &c.): 'Es ist naturgemäss, einen Krystall in regelmässiger Weise aus lauter kongruenten Grundgebilden oder Krystallelmenten aufgebaut zu denken, von denen es allerdings unentschieden bleiben muss, ob sie die aus Atomen zusammengesetzten chemischen Molekeln selbst oder Aggregate von solchen sind . . . von jedem Krystallelemente wird nur der Schwerpunkt in Betracht gezogen. . . . Für die folgende geometrische Untersuchung ist also der Krystall durch ein System diskreter Massenpunkte ersetzt, in welchem es somit stets einen kleinsten Punktabstand giebt.'

If Sohncke had meant to allow the employment of merely geometrical units as crystal elements, he would doubtless have used some such description of them as that which he has given of Haüy's 'molécule soustractive,' of which he says (p. 12): 'Dieselbe hat nämlich zwar eine bestimmte geometrische, aber keine konsequent festgehaltene physische Bedeutung; bald ist sie die wirkliche physische, bald nur eine zu Konstruktionen bequeme geometrische Einheit.'

That he perceived the possibility of employing merely geometrical units is, however, in evidence, for he says (p. 14): 'Bedenkt man . . . dass Delafosse und Seeber nichts anderes gethan haben, als die parallelepipedisch gestaltete substraktive Molekel Haüys durch ihren Mittelpunkt, resp. durch eine kleine ihn umgebende Kugel zu ersetzen, so muss man anerkennen, dass die Haüys'che Theorie hierdurch ganz im Geiste ihres Begründers fortgebildet worden ist und dabei wesentlich an Konsequenz und Einfachheit gewonnen hat.'

[3] *Zeits. Kryst. Min.*, 1892, vol. xx. p. 455.

but also, in the majority of cases, enantiomorphous similarity; for, while in some few crystals the similar faces always bear an identical relation to the whole, in most there are faces that occur in pairs (like a right and left hand), the two individuals of which are enantiomorphously not identically related to the crystal form. Unless this additional factor of enantiomorphous similarity of parts be in some way introduced,[1] Jordan's method gives only the systems of repetition which belong to one or other of the classes of crystal symmetry in which the similarity is all identity, *i.e.*, only such as are enantiomorphs. This significant fact is revealed in the work of the two inquirers, von Fedorow and Schönflies, who established independently and simultaneously that a definition of the symmetrical repetition of parts which includes enantiomorphous similarity as well as identity of parts leads to types belonging to all of the thirty-two classes of crystal symmetry.[2]

Pierre Curie[3] shares with the two writers mentioned above the credit of having established the general principles of repetition by which the symmetry, whether of finite figures, or of systems of figures, or of structures, may be completely investigated. He set himself to consider more general arrangements of points than those dealt with by Bravais. These points may be endowed with qualities independent of direction, such as density, temperature, or with qualities requiring the most varied ideas of direction and orientation, such as velocity, force, intensity of an electric or magnetic field, intensity of power of rotation.[4] (The homogeneous arrangements thus obtained are not all crystallographically possible, *e.g.*, a sphere filled with a rotating liquid.[5]) There are two kinds of repetition—one which leaves everything identically the same as before (*déplacements indifférents*) and another in which the units of one part of the system are the mirror-images of those of the other (*systèmes symétriques l'un de l'autre*[6]). Curie was the first to emphasise the necessity of considering, in addition to ordinary axes and planes of symmetry, axes and planes of alternating symmetry (*plans de symétrie alterne*, *plans de symétrie translatoire alterne*[7]). Although the 230 classes of crystal structure obtained by Schönflies and Fedorow may be deduced from the principles established in his papers, Curie limits himself to deriving the thirty-two varieties of external form which are crystallographically possible.[8]

Another writer of this date of whom mention should be here made is B. Minnigerode, who arrived at the thirty-two classes of crystal systems by means of the theory of groups and substitutions.[9]

[1] This is very clearly brought out by Story-Maskelyne in his *Morphology of Crystals*, Oxford, 1895, p. 99, where the terms 'metastrophic' and 'antistrophic' are employed to distinguish the two sorts of relations.

[2] The discovery of these thirty-two classes by the morphological crystallographers had in fact been due to the use of planes of symmetry and centre of symmetry as the basis of their reasoning; and these elements, of course, contain the conception of enantiomorphous relationship.

[3] 'Sur les questions d'ordre: Répétitions,' *Bull. Soc. Min.*, 1884, vii. pp. 89–111; 'Sur la Symétrie,' *ib.*, pp. 418–457.

[4] *Ib.*, p. 89. [5] *Ib.*, p. 443.

[6] *Ib.*, p. 90. [7] *Ib.*, p. 452. [8] *Ib.*, p. 454.

[9] 'Untersuchungen über die Symmetrieverhältnisse und die Elasticität der Krystalle,' *Nachr. d. k. Ges. d. Wiss.*, Göttingen, 1884, pp. 195–226, 374–384, 488–492; 'Untersuchungen über die Symmetrieverhältnisse der Krystalle,' *Neues Jahrb.*, 1887; Beilage, Bd. v. pp. 145–166.

Schönflies.

Though Arthur Schönflies was not actually the first to establish the existence of the 230 classes of crystal structure, his writings have been the means of making this final development of the subject generally known to the scientific world.[1] His work, which was but little later than that of Fedorow, and is quite independent, culminates in the book 'Krystallsysteme und Krystallstructur,' in which he establishes with the lucidity and rigidity of the skilled mathematician the thirty-two classes of crystal symmetry and the 230 classes of crystal structure, and discusses at length the question of the partitioning of space. It will be convenient to consider the work of Schönflies in some detail in order to treat that of the remaining authors briefly, since many of their results are the same as his.

He adopts Wiener's definition of regularity of structure with this difference: instead of saying that every molecule of an assemblage has the remaining molecules arranged about it in the same manner, he says that every molecule is surrounded by the rest collectively in *like* manner, where 'likeness' of the grouping can either amount to identity or be mirror-image resemblance.[2] The following is an example of the distinction between these two kinds of resemblance: the two points p, q, occupy situations with respect to the cube (fig. 8), which are merely alike, whereas

FIG. 8.

p and p' are identically placed; the cube presents exactly the same appearance when viewed from either of the latter, whereas in the case of p and q the two aspects bear the kind of relation that a right hand bears to a left, or an object to its image as viewed in a mirror. The aspects of the figure from the points p and q may be called enantiomorphous with respect to each other, and any operation which involves such a relationship may be called a mirror-image operation. Schönflies' method is to add to the movements employed by Jordan such processes of inversion and reflection as can be applied to his groups of movements without increasing the number or modifying the character of the actual

[1] 'Beitrag zur Theorie der Krystallstructur,' *Nachr. d. k. Ges. d. W.* 1888, pp. 483–501; 'Über das gegenseitige Verhältniss der Theorien über die Structur der Krystalle,' *ib.*, 1890, pp. 239–250; *Krystallsysteme und Krystallstructur*, Leipzig, 1891; 'Bemerkungen über die Theorie der Krystallstructur,' *Zeits. phys. Chem.*, 1892, ix. pp. 156–170; 'Antwort auf den Artikel des Herrn Sohncke; Zwei Theorieen der Krystallstructur,' *ib.*, 1892, x. pp. 517–525: 'Bemerkungen zu dem Artikel des Herrn E. von Fedorow, die Zusammenstellung seiner krystallographischen Resultate und der meinigen betreffend,' *Zeits Kryst. Min.*, 1892, xx. pp. 259–262; 'Gruppentheorie und Krystallographie,' *Congress Mathematical Papers, Chicago Exhibition*, 1893.

[2] Schönflies, *Krystallsysteme und Krystallstructur*, p. 239.

movements. He thus constructs composite groups of operations which act throughout space, but comprise, in addition to Jordan's groups, certain mirror-image operations with respect to series of parallel planes or to systems of centres of inversion.[1] He calls the groups of operations, whether those of Jordan or those added by himself, 'space-groups' (*Raumgruppen*).[2]

As in the case of Jordan's groups of movements, the symmetry of any given group is rendered easier to trace if a number of similar particles or bodies are placed in all the positions, throughout some considerable space, in which they would be located by applying all the operations of the group to some particular body. In order to accomplish this, in the groups which contain mirror-image operations similar right-handed and left-handed bodies will have to be employed in equal numbers.[3]

It may be maintained that the likeness of parts thus defined by Schönflies, involving as it does two distinct sorts of resemblance—identity and enantiomorphous (or mirror-image) similarity—should scarcely be called, when taken collectively, homogeneity of structure; it would be well, perhaps, if it could be expressed by some new word of wider significance.

Generation of the Various Groups of Operations (Raumgruppen).

Schönflies employs a symbolic method in order to deduce the various types of possible groups of operations.

The following propositions indicate briefly the method pursued by him, without introducing his symbols :—

1. Only such of Jordan's groups of movements as contain a group of translations which all bear finite (and not infinitesimal) relations to one another, and are, therefore, capable of producing a space-lattice (*Raumgitter*), can obey the law of rational indices ; and are, therefore, available for the crystallographer.[4] It is only to these groups that Schönflies applies mirror-image operations.[5]

2. The complete set of translations thus forming part of a Schönflies group of operations must be brought to coincidence with itself (*Deckung*) by every other operation of the group.[6]

3. In addition to planes of symmetry, simple axes of symmetry, and the screw-axes of Sohncke, Schönflies (like Curie) introduces 'planes of gliding symmetry' (*Gleitebenen*)[7] as another possible mode of repetition that can be employed in a group of space-operations. A plane of gliding symmetry is the result of combining reflection over a plane with a translation parallel to that plane.

4. If a given translation, T, be transposed by the operation of a screw axis into another translation, T′, T is also thus transposed by the operation of a *simple* axis of symmetry having the same situation and angle of rotation.

[1] Schönflies, *Krystallsysteme und Krystallstructur*, pp. 334 and 556.
[2] *Ib.*, p. 359. [3] See *Min. Mag.*, 1896, vol. xi. p. 119, and see below, p. 333.
[4] *Krystallsysteme und Krystallstructur*, pp. 360, 636. [5] *Ib.*, pp. 360, 361.
[6] *Ib.*, p. 362. Schönflies calls sub-groups of operations which have this property *ausgezeichnete Untergruppen*.
[7] *Ib.*, p. 367. Schönflies calls that one of the various possible movements about a particular axis which has the smallest angle of rotation and the smallest positive translation the 'reduced movement' (*reducirte Bewegung*).

5. Similarly, if T be transposed into T′ by the operation of a plane of gliding symmetry, T is also so transposed by the operation of a *simple* plane of reflection having the same situation.

6. Hence, corresponding to any given group of operations containing screw axes or planes of gliding symmetry, there exists another group of operations which effect the same changes of direction, but whose elements of symmetry are axes of rotation or planes of reflection, and these are such as belong to a space-lattice.

7. From this it follows that in the groups of space-operations the only axes found are those of the orders characteristic of space-lattices, *i.e.*, digonal, trigonal, tetragonal, and hexagonal axes.

The relations between groups of space-operations (*Raumgruppen*) of different types can be traced by means of the similar relations subsisting between allied ('isomorphous') types of symmetrical operations effected solely about a single point or 'centre' (Punktgruppen);[1] the latter, since the kinds of axes admissible are limited as above, are those which characterise the centred forms of the thirty-two types of crystal symmetry.

Two operations are termed by Schönflies 'isomorphous' when their planes and axes of repetition have the same directions and the angles of rotation of the latter are the same.

A group of space-operations and a group of centred operations are termed isomorphous when every operation of the former is isomorphous with an operation of the latter.

By this method of comparison it is shown that every one of the groups of 'space-operations' involves the general symmetry which governs the symmetry of repetition of like directions in one or other of the thirty-two classes of crystal symmetry.

The mirror-image of a screw movement is a similar movement of the opposite hand. Among the groups of operations corresponding to Sohncke's sixty-five systems which contain screw movements, only such as possess screw-axes of two opposite hands can be utilised for the purpose of deriving groups of space-operations containing mirror-image repetition: such are (1) those which contain screw-axes whose translation component is equal to a half-translation;[2] (2) those which contain for each screw-motion in one direction an equal screw-motion in the opposite direction.

By applying the above principles Schönflies is able to show that the sixty-five systems of Sohncke are increased to 230 groups of operations, all of which, from what has been said, must belong to one or other of the thirty-two types of crystal symmetry.

A complete set of similar plane-directions may be drawn in a Schönflies group of operations, in a way similar to that already indicated for finding identical planes in one of Jordan's infinite groups of movements.[3] Thus:—

[1] *Krystallsysteme und Krystallstructur*, pp. 359, 364, 374, 378, 383.

[2] This case is illustrated by fig. 5, in which the translation component of the axis C (necessary to derive c_1' from c_1) is one half of the translation $c_1\,c_1''$ belonging to the system. Successive points may be regarded as lying either on a right-handed spiral (as $c_2\,c_2'\,c_1''$) or on a left-handed spiral (as $c_1\,c_2'\,c_2''$).

[3] See above, p. 312.

In the given group of operations draw a homogeneous plane in the manner defined above;[1] this plane will, since the translations of the group are not infinitesimal,[2] and develop space-networks, obey the law of rational indices.

Apply to the plane thus drawn the operations of the group; the result is the generation of a system of planes symmetrically distributed through space, all of which are similarly related to the structure regarded as without limits. If mirror-image repetition be not found among the operations of the group, this similarity will amount to identity; if, on the other hand, enantiomorphous operations are present, the planes will form two equally numerous sets, the relation of the one set to the whole being enantiomorphously similar to that of the other set.[3]

Since all the components of the operations of the group which are mere translations are without effect on orientation, the number of different orientations presented by the planes will be strictly determined by the remaining components, and therefore limited.[4] As the component operations of the given group which affect orientation are those characteristic of some one of the thirty-two classes of crystal symmetry,[5] the number of orientations presented in the given case will be the same as in such class;[6] *i.e.*, there will be as many infinite sets of parallel planes as there are different orientations. The planes of each set, since they have to obey the translations found in the group, will be equidistant. Among the 230 different types, there are many in which it is possible to select from the set of planes one of each orientation in such a way that the planes selected enclose a space, but in some only of the types thus characterised can the planes be so chosen as to outline a symmetrical polyhedron whose axes are axes of the system; for the remainder centred enclosures of this symmetrical character are impossible.[7]

With the aid of the above conception of a system of similar planes it is not difficult to verify the following propositions:—

1. The application of an additional movement or enantiomorphous operation to a group, provided the system of axes, planes of symmetry, and other features essential to the group are brought to coincidence (*Deckung*) by this new operation, will lead, when the latter is completely combined in every possible way with those previously present, to the evolution of a derived Schönflies group of operations.[8] This derived

[1] See above, p. 312. The direction of the plane is not to be a specialised one, except so far as premised by the definition: this will ensure that every operation of the group shall effect a change of position of the plane.

[2] See *Krystallsysteme und Krystallstructur*, pp. 360 and 636, and Proposition (1) above.

[3] Cf. *Krystallsysteme und Krystallstructur*, pp. 361, 362.

[4] *Ib.*, p. 363. *Cf.* Prop. (6) above.

[5] Cf. *Ib.*, pp. 363–364, 599, and 637.

[6] *Cf.* Prop. (7) above and *Phil. Mag.*, 1901, series 6, i. p. 21. As is the case in some of the latter, planes inclined at 180° will be distinguished from one another, the two sides of a plane being discriminated

[7] *Cf.* p. 31. As all the existing evidence as to the ultimate relative situation of crystal faces concerns *their direction only*, the question whether in a given system of similar planes regular polyhedral cells are present or not does not as yet affect the crystallographer.

[8] *Krystallsysteme und Krystallstructur*, p. 383. Schönflies sums up his method in the following fundamental proposition: 'Lässt sich die Punktgruppe G durch Multiplication einer Gruppe G_1 mit einer Operation $\mathfrak{L}^1$ erzeugen welche das Axen-

group, as compared with the group from which it was obtained, will in different cases present—

a. A greater number of orientations of the planes belonging to the derived system.

b. The same number. In this case the change will consist solely in the increased closeness of the planes of a set, and the type among the 230, which is exhibited, will sometimes be different, sometimes the same.

The converse proposition is—

2. The withdrawal of some operations from a group, entailing the symmetrical omission of some of the sets of parallel planes, or of some of the planes in each set, leads to the derivation of a distinct group of operations. There will in different cases be—

α. Fewer directions of orientation for the planes in the derived group.

β. The same number of directions, associated in some cases with the preservation of the same type, in some cases with the development of a different type among the 230.

As a simple example of the application of the principles established above consider the hemimorphous class of the monoclinic system.[1] It possesses an axis of two-fold symmetry, which in the space-group may appear as an axis of rotation or as a screw-axis. Now, in the monoclinic system there are two lattices: one rhomboidal and the other composed of rhomboidal prisms with centred faces. We obtain two groups from the former by combining it with an axis of rotation, and with a screw axis; from the latter we obtain only one group, since in this case the same group is derived by the addition of either set of axes.

Like Jordan's groups, those traced by Schönflies are really mere groups of geometrical processes, independent of the nature of the material system concerned; but it is convenient to regard the processes as applied to something more tangible. Schönflies himself supplies this want by introducing the conception of atomic structure, and of its definite partitioning. Here the reader must beware lest the nature or configuration of the atoms or particles themselves be confounded with the nature and distribution of the structure considered with respect to them, and lest the possibilities of mere geometrical partitioning be confounded with those of a partitioning into conceivable physical units.[2]

Schönflies treats his work of discriminating 230 types of groups of operations (Raumgruppen) as preliminary to a direct application of his results to a molecular theory of matter, which he sets before himself from the outset; the reader might, therefore, suppose that the existence of molecules with void spaces between them is essential in order that the geometrical derivation of the 230 types may be applicable to crystals.[3] Thus Schönflies says: 'By a *regular* assemblage of molecules of unlimited extent is understood a molecular assemblage infinitely extended in all directions, which consists entirely of similar molecules, and possesses the property that around every molecule the disposition of the infinite system formed by the other molecules is similar.'[4] And a little later he lays

system von G_1 in sich überführt, so kann jede zu G isomorphe Raumgruppe durch Multiplication einer zu G_1 isomorphen Gruppe Γ_1 mit einer zu $\mathfrak{L}^1$ isomorphen Operation $\mathfrak{L}$ erzeugt werden, vorausgesetzt, dass $\mathfrak{L}$ eine Deckoperation für die Axen von Γ_1 ist.'

[1] *Krystallsysteme und Krystallstructur*, p. 406.

[2] Cf. *Min. Mag.*, 1896, vol. xi. p. 129.

[3] *Krystallsysteme und Krystallstructur*, p. 237.

[4] *Ibid.*, p. 239.

down the fundamental hypothesis that 'a homogeneous crystal displays the property that around every point in its interior the structure is that of a regular assemblage of molecules of unlimited extent.'[1]

This way of stating his case imparts to Schönflies' extension of the methods of Jordan and Sohncke a somewhat hypothetical aspect, and, perhaps, obscures the fact that the characteristic symmetry presented by crystals is traceable in the groups of movements and mirror-image operations without specifying the kind of structure employed, and merely postulating the nature of its homogeneity—*i.e.*, the type which it presents.

In reality his work is not based on an assumption as to the nature of the regular repetition in space of hypothetical elements in a crystal,[2] but its application to crystals rests on the assumption that the parallelism between the properties of his regular configurations and the crystal properties is due to a common cause; in other words, that the arrangement or symmetrical repetition of the ultimate parts in crystals is that characteristic of these configurations. Schönflies endeavours, in fact, to ascertain what special suppositions as to the form and quality of the molecule lie at the root of all theories of the constitution of crystals, and to determine what further consequences are implicitly bound up with these suppositions.[3]

The atoms and molecules of Schönflies are, properly speaking, mere cells or geometrical space-elements, into which a homogeneous structure is divided by some sort of symmetrical partitioning, the symmetry or want of symmetry attributed to the former being in reality a feature of these cells. Schönflies speaks of placing molecules in cells previously obtained by some symmetrical partitioning of space, but it will be found that their individual properties are those of the cells, and are not necessarily adequately descriptive of the symmetry of bodies contained in the cells considered irrespective of the latter. The statement that the characteristic symmetry of the molecule is identical with the symmetry of the cell allotted to it by the symmetrical partitioning would not be true of a highly symmetrical physical molecule put into a cell having little or no symmetry.

Schönflies attaches considerable importance to the idea of an *elementary cell* (*Fundamentalbereich*),[4] which he introduces in chapter xiii. of the second part of his work, and it will not be out of place to give a word or two of explanation.[5] He shows that any system possessing a group of operations as above defined may be divided into an infinite number of contiguous polyhedra, which are all similar to one another, and, in general, of two kinds, the polyhedra of one kind being identical with those of the same kind, and the mirror-images of those of the other kind. Each of these polyhedra encloses one and only one point of a given kind in the partitional system, round which point matter is distributed in a given manner.[6] The form of the cell is, in general, indeterminate, but it is subject to certain conditions; it cannot be cut by an element of symmetry of the crystallised body; if it possesses a plane of symmetry, this plane must coincide with a face of the cell, and, further, centres and axes of symmetry must lie on the surface of the cell.[7] From any one of

[1] *Krystallsysteme und Krystallstructur*, p. 239. [2] *Ibid.*, p. 247.
[3] *Ibid.*, pp. 248, 614. [4] *Ibid.*, p. 559.
[5] The following discussion of the subject is borrowed from an interesting paper on 'Théorie des anomalies optiques, de l'isomorphisme et du polymorphisme,' by Fréd. Wallerant, *Bull. Soc. Min.*, 1898, vol. xxi. p. 197 *et seq.*
[6] *Krystallsysteme und Krystallstructur*, p. 572. [7] *Ibid.*, p. 573.

these cells the remainder can be found by means of the group of operations. Most of the 230 types can be partitioned into space units which individually possess the symmetry of the system as a whole. When this is the case, a finite group of contiguous elementary cells will form such a unit and can be found by applying to one of them certain of the elements of symmetry which lie on its surface; a symmetrical space unit of this kind may be called a *complex cell*.[1] Other complex cells possessed of less symmetry can, of course, be formed. Some of the 230 types, while capable of being partitioned into such less symmetrical complex cells cannot be partitioned into complex cells which have as high a symmetry as that of the type. For example, the type represented by the Sohncke system described above (fig. 5, p. 314) can be partitioned into cells possessing trigonal axes with or without centres of symmetry or planes of symmetry, or with both, but its cells cannot individually possess an hexagonal axis.

As an example, take the case of the hexagonal space-lattice of

FIG. 9.

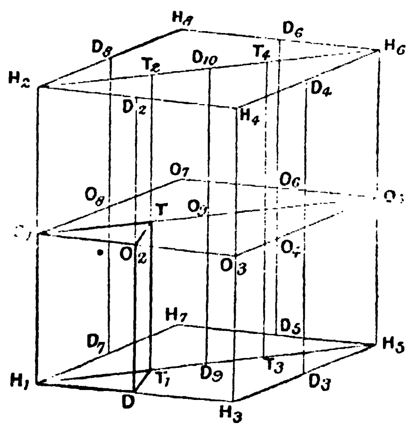


fig. 2, where the axes are axes of rotation and the planes of symmetry are planes of reflexion. The shape of the bodies placed at the points is ignored, or in other words they are supposed to have a symmetry which does not modify that of the system of arrangement. The points H in fig. 9 constitute such a space-lattice. In this figure $H_2H_4H_6H_8$ correspond respectively to $\alpha, \gamma, \delta, \beta$ of fig. 6. H_1H_2 is an hexagonal axis of rotation. Take H_1 as the origin of this Bravais-system, which we know is a perpendicular prism with a rhomb of 60° as base. All the rows of the system parallel to H_1H_2 are also hexagonal axes of rotation. By combining these rotations with the translations of the system we see at once that straight lines such as T_1T_2, T_3T_4, which are parallel to the hexagonal axes and pass through the centres of gravity of the equilateral triangles forming the bases of the lattice, are trigonal axes of rotation; and, again, straight lines such as D_1D_2, D_3D_4, D_5D_6, D_7D_8, D_9D_{10}, which pass through the middle points of the rows of the base, are digonal axes of rotation.

[1] *Krystallsysteme und Krystallstructur*, p. 576.

Six planes of reflexion pass through the hexagonal axis, H_1H_2, making angles of 30° with one another (such are the planes $H_2H_4H_3$, $H_2H_6H_5$, and $H_2H_8H_7$), and, parallel to these planes, there must be throughout the structure a series of equidistant planes of reflexion.

Further, there is a centre of symmetry on the hexagonal axis; we may suppose it to coincide with H_1, since this was arbitrarily chosen. All the nodes of the Bravais-system are such centres of symmetry, and in addition all the middle points of the rows, *i.e.*, all, the points H, D, and O.

Further, the presence of this centre combined with the hexagonal axis necessitates the existence of planes of reflexion perpendicular to the axis and passing through the centres, and, consequently, separated from one another by O_1H_1, half the parameter, H_2H_1, of the axis. Also, perpendicular to each of the planes passing through the hexagonal axis there are a series of diagonal axes of rotation passing through the centres of symmetry lying on these planes.

Such, then, are, in the case in question, the elements of crystalline symmetry which fill space.

The elementary cell is easily determined, since the elements of symmetry must lie on its surface: it is the right prism with triangular base $O_1O_2TH_1D_1T_1$, which has its bases in two principal planes; its edges are a hexagonal axis H_1O_1, a trigonal axis T_1T_2, and a digonal axis D_1O_2; its side faces are three planes of symmetry; the four corners H_1, D_1, O_2, O_1, are centres of symmetry, but the corners TT_2, situated on the trigonal axes, are not centres.

To obtain the complex cell we must apply to the fundamental cell the appropriate elements of symmetry—*i.e.*, in this case the hexagonal axis and two planes of symmetry, $O_1O_2H_1D_1$ and $H_1D_1T_1$—whence we obtain a right prism with hexagonal base whose edges are the trigonal axes, *i.e.*, the cell of fig. 3.

(By taking another set of the primary elements of symmetry another complex cell will be obtained.)

A corresponding crystalline structure will be obtained by furnishing each elementary cell in a similar manner with contents of any nature.

Fedorow.

As has been said above, the 230 types of crystal structure were independently established and investigated by E. von Fedorow.

The researches of this author which relate to the subject of crystal structure begin in the year 1885 with a general treatise on the 'Theory of Figures,' published (in Russian) with copious illustrations in the 'Transactions of the Russian Mineralogical Society,' xxi. pp. 1–279: this was followed in 1888 by a memoir on the 'Symmetry of Finite Figures,' published (in Russian) in the same journal, xxv. pp. 1–52, and by one on the 'Symmetry of Regular Systems of Figures,' published (in Russian) in 1890.

The above are not only among the earliest treatises on these subjects, but they contain also almost all that is essential in the author's later development of it, and some results that have been independently published by other investigators to whom his Russian papers were not known. An abstract of some of the early papers was given by Wulff[1] and by Fedorow himself.[2]

[1] *Zeits. Kryst. Min.*, 1890, vol. xvii. p. 610. [2] *Ib.*, 1893, vol. xxi. p. 679.

Fedorow first established the principle that in a symmetrical figure the symmetry must be one or more of the following sorts : axis of symmetry, plane of symmetry and a combination of the two, or composite symmetry (*i.e.*, Curie's alternating symmetry) ; in a regular system of figures, on the other hand, supposed infinitely extended, two more general elements of symmetry are also possible—namely, a screw axis and a glide-plane of symmetry ; repetition about a screw axis consists of a rotation combined with a translation along the axis ; repetition about a glide-plane consists of reflexion combined with a translation parallel to the plane. The elements of symmetry in a finite figure are simply special cases of the latter in which the translations are zero.

Like Hessel, Fedorow investigated first the symmetry of finite solid figures in general and then, by limiting the problem by a condition equivalent to the law of rational indices, deduced the thirty-two kinds of symmetry possible for crystals. His method consists practically in combining any two of the possible elements and ascertaining to what other elements they give rise : *e.g.*, two axes of digonal symmetry inclined at 45° give rise to the axes of a trapezohedral tetragonal crystal ; the total group constitutes a '*Symmetrie art*' or 'class.'

Two classes are different when in one of them an axis (or, in general, a symmetry element) is present which is absent from the other, or occupies a position which it does not occupy in the other. Such a class, therefore, corresponds to a 'group of operations' in the language of Schönflies.

A special feature of Fedorow's researches is his analytical expression of the symmetry ; this is described in the second of the above-mentioned memoirs. In this method a point is denoted by an indefinite number of coordinates (although three are sufficient)—namely, the intercepts made upon all the axes, derived by the symmetrical repetition of one coordinate axis, by planes drawn perpendicular to them through the given point.

Thus, if an axis of p-fold symmetry be taken as one coordinate axis y, and a line perpendicular to it as a second coordinate axis y_0, then repetition of y_0 about y gives $p-1$ other coordinate axes, y_1, y_2, &c. A point whose coordinates are $y=b$, $y_0=b_0$, $y_1=b_1$ then gives rise to a symmetrical set of points $y=b$, $y_0=b_s$, $y_1=b_{s+1}$, where s may have the different values 0, 1, 2 . . . $p-1$. By means of equations of this nature, containing also appropriate symbols for repetition about the planes of symmetry, the various sorts of symmetry of figures or of regular systems of figures are deduced and expressed. The method by which they are deduced consists practically in seeking all the possible combinations of the elements of symmetry which are not incompatible with each other.

In the first memoir, which deals only with the symmetry of finite figures, after establishing all the possible varieties of regular polyhedra and classifying them as isogons (which have similar or symmetrical edges), and isohedra (which have similar or symmetrical faces), and having shown that there are eighteen sorts of typical isohedra,[1] Fedorow investigates their symmetry according to the principle that each class (*Symmetrie art*) corresponds to certain typical isohedra, and, conversely, that when all the typical isohedra are known the various classes of symmetry can be deduced from them. Crystal polyhedra are treated as special cases.

[1] A typical isohedron is the figure derived from a polyhedron by moving its faces parallel to themselves until they all touch one and the same sphere.

The second part of the memoir considers the regular partitioning of a plane, and of space, and the nature of zonohedra, or figures whose faces intersect in parallel edges, and shows that there are six kinds of zonohedra. [Here also the author lays down the principles of simple elongation (*Zug*) and Shear (*Verschiebung*), and shows that any parallelepiped may be transformed into any other by these two processes. These principles are chiefly of importance in Fedorow's development of his own theory of crystal structure, and of his methods of calculation.]

With regard to the partitioning of space, it is shown that space may be filled either by equal figures ranged parallel to one another; these are called 'parallelohedra'; or by polyhedra, which, while equal or symmetrically similar, are not necessarily parallel: these are called 'stereohedra.'

The plane-faced parallelohedra are bounded by pairs of parallel faces (*i.e.*, they possess centro-symmetry), and their arrangement is necessarily that of a space lattice. There are four sorts of such parallelohedra, namely, those with three, four, six, or seven pairs of parallel faces; and the filling of space with these corresponds to the close packing of spheres which are in contact with six, eight, twelve, or eight neighbouring spheres respectively. Fedorow's most general sort of parallelohedron, the fourth of those mentioned above, the 'heptaparallelohedron,' is identical with the 'tetrakaidekahedron' subsequently and independently established by Lord Kelvin as the most general parallel-faced cell into which space can be regularly partitioned;[1] its superficial area is, as was shown by both authors, a minimum for a given volume.

When space is partitioned into differently orientated identically similar plane-faced stereohedra, these may always be grouped together into sets, such that each set is a parallelohedron; further, the analogous points of the stereohedra constitute a regular point-system, just as the analogous points of the parallelohedra constitute a space-lattice. Here, then, we have a statement of the fact that the points of a regular point-system can always be grouped into clusters whose arrangement is a space-lattice.

As will be seen hereafter, this conception of parallelohedra, as opposed to stereohedra, forms the basis of Fedorow's own theory of crystal structure.

The last section of the memoir is occupied with the consideration of polyhedra with concave faces, or 'koilohedra.'

In his second treatise, that dealing with regular systems of figures,[2] the problem of crystal structure is more directly approached. A regular system of figures is defined as consisting of an infinite assemblage of finite figures, such that when any two of them are made to coincide by one of the processes of symmetrical repetition (including herein the mirror-image repetition to be mentioned presently) the whole system coincides with itself again. This is, of course, practically the same as the definition of Schönflies, and must lead to the same results.

If any point in one of the figures be chosen, and the homologous points in all the figures of the system be sought, the whole complex constitutes a regular point-system.

Those point-systems in which only repetition about axes (screw or other) or simple translation is involved correspond to Sohncke's systems,

[1] *Proc. Roy. Soc.*, 1894, lv. p. 1. See also *Phil. Mag.*, 1887, xxiv. p. 503.
[2] See for a short account *Zeits. Kryst. Min.*, 1892, vol. xx. pp. 39–62.

and are called 'simple'; the remainder may be regarded as consisting of two 'analogous' systems, the one the mirror image of the other, and are called 'double systems.'

The systems, as a whole, are divided into three groups: (1) Symmorphous, whose elementary figures possess the same class of symmetry as the system itself; (2) hemisymmorphous, consisting of two analogous symmorphous simple systems, which together make up a 'double system,' the latter itself not being symmorphous; (3) asymmorphous. In the first class all the elements of symmetry meet in a point within each figure; in the second class only the symmetry axes meet in a point; in the third class none of the elements of symmetry meet in a point; here, consequently, adjacent figures are differently orientated.

Fedorow first proves that the classes of symmetry of the regular systems of figures are only special cases of the classes of symmetry of the finite figures, and that it is possible to have several regular systems belonging to the same class of symmetry.

The classes of symmetry are, of course, thirty-two in number; they are limited by virtue of the fact that the axes, whether symmetry axes, screw axes, or axes of composite (alternating) symmetry, can only be two-fold, three-fold, four-fold, or six-fold.

The definition of the regular partitioning of space given by Schönflies [1] is practically identical with that given by Fedorow in his 'Elements of Figures' in 1885: 'A division of space into absolutely similar cells in which each cell is surrounded in the same way by the remainder.' If in a regular system of figures all the figures dilate uniformly until they come into contact, the system is converted into one of cells regularly partitioning space. A noteworthy property of the 'elementary' or minimum cells is that the axes and planes of symmetry of the system cannot pass through them,[2] but must lie in their surfaces; in other respects unless bounded on all sides by planes of symmetry their actual form is quite arbitrary.

Here, again, Fedorow introduces the classification mentioned above: (1) Symmorphous systems have the same symmetry as their cells; here the cells are parallelohedra,[3] and therefore arranged in parallel positions; *e.g.*, an arrangement of parallel cubes; (2) hemisymmorphous systems, which only have the elements of simple translation and rotation in common with the constituent cells; *e.g.*, the triangular prisms of fig. 1; here the parallelohedron (rhombic prism of 60°) is composed of two 'analogous' stereohedra (two triangular prisms); (3) asymmorphous systems in which the parallelohedra are indeterminate and not necessarily closed polyhedra.

Now a parallelohedron possesses a centre of symmetry (centre of inversion), and if it is a convex figure this centre lies within it; if, on the other hand, it is concave, the centre lies without it. Further, in every convex parallelohedron the faces are only parallel and equal in pairs; and there are only four sorts of parallelohedra, namely, those

[1] *Nachr. d. k. Ges. d. Wiss.*, Göttingen, 1888, ix. p. 223. [2] See above, p. 326.

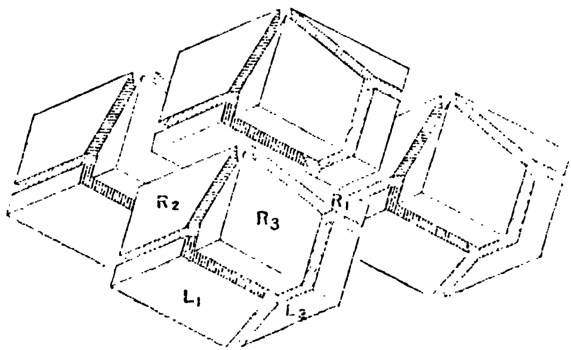
[3] Like Haüy's *molécules soustractives* Fedorow's parallelohedra are mere geometrical entities, and in many cases the grouping of the stereohedra which produces them has to be very arbitrary. The same stereohedra can in all cases be grouped to form parallelohedra in an infinite number of ways. The parallelohedra will often have re-entrant angles even if the angles of the stereohedra of which they are composed are all salient.

mentioned above, which possess respectively three, four, six, and seven such pairs of faces.

The following example illustrates the principles described above, and is of special interest as representing a type consistent with the symmetry of the mineral dioptase which first led to an extension of Sohncke's theory. This mineral possesses an axis of trigonal combined with a centre of symmetry, its faces always occurring in sets of six, which are all alike, and consist of three pairs of parallel faces. (The symmetry may equally well be described as due to the operation of an hexagonal axis of alternating symmetry.)

Fig. 10 represents a system of stereohedra arranged in accordance with this symmetry: the stereohedra are of two sorts (R and L), one sort being the mirror-image of the other; the structure is symmorphous. A series of points similarly situated, one within each stereohedron R, would constitute a Sohncke-system: a 'double system' of points is obtained by adding a series similarly situated, one within each stereohedron L. The figure also shows the manner in which the stereohedra

FIG. 10.[1]



can be grouped in sets of six to form parallelohedra, which in this case are rhombohedra. Consequently a rhombohedral partitioning of space is consistent with the given type of symmetry.

From the principles laid down in the memoirs mentioned above, Fedorow is able to deduce all the possible types of symmetry which characterise either homogeneous systems of figures, or homogeneous systems of points, or the homogeneous partitioning of space.

They are 230 in number, and are identical with those established independently, as stated above, by Schönflies.

Fedorow's theory of crystal structure, which is based upon his parallelohedra, will be considered later.

Barlow.

The result attained by Fedorow and Schönflies, that homogeneous structures, if classified by their symmetry, can be distinguished not only into thirty-two classes but into 230 kinds which belong to these thirty-two

[1] The stereohedra are shown in the figure slightly drawn apart to make the arrangement clearer, but in fact they fill space without interstices.

classes, was arrived at by William Barlow[1] by a somewhat different reasoning.

The sixty-five point-systems of Sohncke are of two sorts: some of them are identical with their own mirror-images and some are not. Further, there are some very simple homogeneous structures which are not *fully* represented among Sohncke's systems. An example will be given directly.

Barlow designates the identical symmetrical repetition of parts throughout space, as investigated by Jordan and Sohncke, by the title 'homogeneous structure,' and his definition of such a structure is very similar to that given by Fedorow of a regular system of figures. He shows that the point-systems obtained by taking all the homologous points in such a structure are Sohncke's point-systems, and that every such structure is capable of the coincidence-movements of some one of Sohncke's sixty-five systems and of no other.

Suppose, for example, a number of equal cubes to be stacked together in the most regular manner, and let any geometrical point be taken within one of the cubes. There are within this cube twenty-three other points, at the same distance from its centre as the first, which have identically[2] the same relation to the whole stack, so that the latter presents the same aspect when viewed from any one of the twenty-four points.

These twenty-four points constitute a Sohnckian 24-punktner, and when corresponding points are taken in all the cubes Sohncke's system 59 is obtained.

By a method of developing structures of higher symmetry from those of lower symmetry, Barlow obtains all Sohncke's sixty-five sets of coincidence-movements, and points out that corresponding to each of these sixty-five systems is a class of homogeneous structure which is *not identical with its own mirror-image*. He then remarks that the additional property of identity with mirror image can be displayed by homogeneous structures in a definite number of different ways, and that this enables us to distinguish other types of symmetry besides the sixty-five types established without this property.

For example, let a line be drawn from each point of one of the 24-point groups above described through the nearest cube-centre, and prolonged to an equal distance on the opposite side. The twenty-four points thus obtained, together with all similar points, constitute a second Sohncke-system which is the mirror image of the first; from each of them the aspect of the structure as a whole is the mirror-image of its aspect from any one of the first set. The two together represent fully the true symmetry of the stack of cubes, which is thus shown to possess a higher symmetry than the simple Sohncke-system derived from it.

If, now, space is to be filled with similar *unsymmetrical* cells, instead of cubic cells, one such cell must enclose each of the first system of points, and another which is its mirror-image must similarly enclose each of the second system of points. In the original paper the diagrams of symmetrical partitioning which are introduced make this conclusion easier to follow. The cells clearly correspond to the *Fundamentalbereiche* of

[1] 'Ueber die geometrischen Eigenschaften homogener starrer Structuren und ihre Anwendung auf Krystalle,' *Zeits. Kryst. Min.*, 1894, vol. xxiii. pp. 1–63; and 1895, xxv. p. 86.

[2] Points having a mirror-image relation to the point selected are not here taken into consideration.

Schönflies, and must, as stated above, contain on their walls all the elements of symmetry of the structure.

The double system just obtained might have been constructed in another way. Thus, draw a line from each point of the 24-punktner perpendicular to a plane of symmetry of the structure, and produce it to an equal distance on the opposite side; the system so obtained is identical with that previously obtained by the employment of centres of symmetry.

A homogeneous structure consisting of material of any sort or shape which contains points of two kinds like the above is identical with its mirror-image.

All the possible types of homogeneous structures are constructed in the following way. Take a Sohncke point-system and, where possible, insert into it the mirror-image of itself (*i.e.*, the enantiomorphous Sohncke-system) in such a way that the coincidence-movements of the two coincide (*e.g.*, the Sohncke-system obtained from R of fig. 10, combined with that obtained from L).

The two constituent systems are then related to each other in one or more of three modes, either (1) across a centre or centres of symmetry so that they are oppositely orientated in every direction, or (2) across a plane or planes of either ordinary or gliding symmetry, or (3) they are opposed to each other with reference to one direction and are at the same time orientated at right angles to each other.

His third mode is in reality the method of repetition, used by Fedorow, Schönflies, and Curie, which has an axis of alternating symmetry; Barlow employs it only in the case of the tetartohedral symmetry of the tetragonal system because the other types which possess symmetry of this nature possess also the symmetry of one of the other two modes, and have therefore been already found.

By applying these three modes of duplication to Sohncke's sixty-five systems, Barlow deduced the same 230 types of symmetry which were distinguished by Fedorow and Schönflies.

The table of the 165 additional systems given by Barlow has this advantage, that it distinguishes clearly the enantiomorphous systems from those which possess mirror-image symmetry, and shows the mutual relations of the two enantiomorphous systems of which a double system consists, and further indicates the exact position of some of the centres and planes of symmetry in the structure.

Points of the structure which lie at these centres or upon axes or planes of symmetry ('singular points' of Barlow) are clearly less numerous than any other sets of homologous points in the structure. In the stack of cubes, for example, the centres of the cubes are less numerous than the most general sorts of homologous points within the cubes. As explained above, there are two sets of twenty-four points each surrounding each centre; it is evident, therefore, that the least symmetrically situated points are no less than forty-eight times as numerous as the centres.

Barlow's theory of crystal structure, which is based upon the principle of close-packing, will be considered later.

Any account of the geometrical theories of crystal structure which omitted reference to the important work of Lord Kelvin would be very incomplete. This author has investigated the problem of the homogeneous partitioning of space, and, as was mentioned above, established independently the tetrakaidekahedron (Fedorow's heptaparallelohedron)

as the most general form of cell belonging to such partitioning. The fourteen walls of this cell are not necessarily plane.[1]

Most of his papers cited below relate to the equilibrium of molecular systems, and will therefore be more properly considered later in connection with that branch of the subject. A discussion of the relationship between the three aspects of the problem of crystal structure—namely, homogeneous assemblages of points, partitioning of space, and close packing of similar bodies—forms, however, an important part of the 'Boyle Lecture' published in 1894.[2]

The assemblages of points considered by Bravais and Sohncke may be replaced by solid bodies in contact with each other, or by close-fitting cells; so also, in the more general case, the *Fundamentalbereiche* of Schönflies may be occupied by points, by solid bodies, or by portions of solid bodies. Lord Kelvin considers these problems on the basis of the Bravais assemblage, and treats very fully of the partitioning of space into identical sameway-orientated cells. His definition of homogeneity is therefore more limited than that of the writers subsequent to Bravais. Thus he says: 'The homogeneous division of any volume of space means the dividing of it into equal and similar parts, or cells, all sameways-oriented. If we take any point in the interior of one cell and corresponding points of all the other cells, these points form a homogeneous assemblage of single points, according to Bravais' admirable and important definition. The general problem of the homogeneous partition of space may be stated thus: Given a homogeneous assemblage of single points, it is required to find every possible form of cell enclosing each of them subject to the condition that it is of the same shape and sameways-oriented for all.'[3]

The manner in which the physical and morphological properties of a substance may be represented by a geometrical cell-partitioning is illustrated by Lord Kelvin's elegant model of quartz described in the Boyle Lecture.[4]

Among the systems studied by Lord Kelvin are those of atoms endued with inertia and held in equilibrium by Boscovichian attractions and repulsions.[5] As a possible structure for an ice crystal, for example, composed of Boscovichian atoms, according to this principle, a system is proposed consisting of two interpenetrating space-lattices of rhombohedral symmetry.[6]

William Barlow, again, in a paper entitled 'A Mechanical Cause of Homogeneity of Structure and Symmetry geometrically investigated,'[7] has given numerous examples of the manner in which stacks of close-

[1] 'On Homogeneous Division of Space,' *Proc. Roy. Soc.*, 1894, lv. pp. 1–16; 'On the Division of Space with Minimum Partitional Area,' *Phil. Mag.*, 1887, ser. 5, xxiv. pp. 503–514; 'The Molecular Constitution of Matter,' *Proc. Roy. Soc. Edin.*, 1889, xvi. pp. 693–724.

[2] 'The Molecular Tactics of a Crystal,' The Second Boyle Lecture, 1894, Oxford.

[3] *Proc. Roy. Soc.*, 1894, lv. p. 1.

[4] P. 52. *Cf.* also 'Piezo-electric Property of Quartz,' *Phil. Mag.*, 1893. ser. 5, xxxvi. pp. 331–340.

[5] 'The Elasticity of a Crystal according to Boscovich,' *Phil. Mag.*, 1893, ser. 5, xxxvi. pp. 414–430, and *Proc. Roy. Soc.*, 1894, liv. pp. 59–75.

[6] 'On the Molecular Dynamics of Hydrogen Gas, Oxygen Gas, Ozone, Peroxide of Hydrogen, Vapour of Water, Liquid Water, Ice, and Quartz Crystal,' *Report Brit Assoc.*, 1896, pp. 721–724.

[7] *Proc. Roy. Dub. Soc.*, 1897, viii. pp. 527–690.

packed spheres, either equal or of two or three different sizes (representing the atoms), may be constructed so as to possess the symmetry of many holohedral, hemihedral, or tetartohedral crystals, and to be in harmony with their physical properties.[1]

Among recent writers mention should be made of C. Viola. He has employed the method of quarternions to derive the thirty-two classes of crystal symmetry[2] and has also given an elementary exposition of these classes based upon the planes of symmetry.[3] In a recent paper[4] he questions the ultimate validity of the law of rational indices.

It is sufficient here to point out that all the systems devised by Kelvin, Barlow, Turner, Sollas and others, being homogeneous arrangements, must correspond geometrically to one or other of the 230 types of Schönflies and Fedorow, and must all, as to their symmetry, be ultimately reducible to a certain number of interpenetrating space-lattices. As they go beyond the geometry of the subject their consideration is postponed for the present.

Summary.

With the establishment of the 230 types of structure the purely geometrical study of the problem seems to have attained something like finality. The history of its development, as sketched above, is the history of an attempt to express geometrically the physical properties of crystals, and at each stage of the progress an appeal to their known morphological properties has driven the geometrician to widen the scope of his inquiry and to enlarge his definition of homogeneity in order that it may include types of symmetry which did not fall within the more restricted definition. The necessity of explaining hemihedrism led to the system of Sohncke; the necessity of accounting for the known symmetry of dioptase led to the further extension of Sohncke's principles.

The two most satisfactory features of the final geometrical solution of the problem are the following: (1) A single principle—namely homogeneity according to the wider definition—is sufficient to account for the two leading characteristics of crystals, their aolotropism, and the law of rational indices. (2) The lines are now laid down within which speculation concerning the actual structure of any crystallised substance can range.

There are three problems to be solved in explaining the structure of crystals: (1) What are the parts of which a crystal consists? (2) How are they arranged? (3) Why are they arranged in this particular way?

We have now good reason to believe that a partial answer has been found to the second question, and that whatever may be the parts of which a crystal consists they must be arranged according to one or other of the 230 types of symmetry; Sohncke systems and Bravais space-lattices are, of course, special cases of these.

[1] Compare also A. Turner, *Das Problem der Krystallisation*, Leipzig, 1897, and W. J. Sollas 'On the Intimate Structure of Crystals,' *Proc. Roy. Soc.*, 1898, lxiii. pp. 270-300; 1901, lxvii. pp. 493-496.

[2] Ueber die Symmetrie der Krystalle und Anwendung der Quaternionrechnung, *Neues Jahrb.*, 1896, Beilage Bd. x. pp. 495-532.

[3] Elementare Darstellung der 32 Krystallklasse, *Zeits. Kryst. Min.*, 1897, xxvii pp. 1-40.

[4] Zur Begründung der Krystallsymmetrien, *Ibid.*, 1901, xxxiv. pp. 353-388.

It is true that by placing suitable bodies (molecules endowed with certain symmetry) at the nodes of a space-lattice all the properties of a crystal may be accounted for, but there seems no sufficient reason for limiting the problem in this manner. The material occupying the *Fundamentalbereiche* of Schönflies, or represented by a generalised point-system, may always be supposed grouped about the nodes of the underlying space-lattice if required, so that what were at first regarded as so many units come to be the parts of a single composite unit; but in some cases the latter, like some of Haüy's *molécules soustractives*, must be a mere geometrical fiction.

Until we know more about the units of which the crystal really consists, there will necessarily be speculation as to whether the units are situated at the most general sorts of homologous points in a given type, or whether they are symmetrical bodies situated at the singular points; whether they are all of the same sort or of more than one sort.

It is proposed to consider in a subsequent report some of the mechanical and physical conceptions which have been employed in discussing the possible structure of crystals, and the definite structures recently ascribed to certain substances.[1]

The Movements of Underground Waters of North-west Yorkshire.—Second Report of the Committee, consisting of Professor W. W. WATTS (*Chairman*), Mr. A. R. DWERRYHOUSE (*Secretary*), Professor A. SMITHELLS, Rev. E. JONES, Mr. WALTER MORRISON, Mr. G. BRAY, Rev. W. LOWER CARTER, Mr. W. FAIRLEY, Mr. P. F. KENDALL, *and* Mr. J. E. MARR.

THE Committee are carrying out the investigation in conjunction with a committee of the Yorkshire Geological and Polytechnic Society.

The work of investigating the flow of underground water in Ingleboro', described in the report presented to the Association at the Bradford meeting, was resumed by the Committee on November 10, 1900, when it was determined to study the underground course of a small stream known as Hard Gill.

This stream rises, on the south side of Ingleboro', in a spring at 1,600 feet above the sea, and flows for a distance of about half a mile over boulder clay.

It then reaches the bare limestone and commences to sink near the eastern corner of the croft at Crina Bottom.

In wet weather the stream is not entirely absorbed at this point, but flows on past the house at Crina Bottom, and enters the rock at Rowan Tree Hole (Rantree Hole on 6-in. map).

At the time of the experiments the water of Hard Gill was entirely absorbed between the point where the 1,200 feet contour crosses the stream and the eastern corner of the croft, and consequently the investigation of Rowan Tree Hole, the primary object of the excursion, had to be abandoned.

It was found, however, that the bulk of the water was absorbed at the point where the 1,200 feet line crosses the stream, and consequently

[1] This relates to work published by Mallard, Liveing, Fedorow, Kelvin, Wulff, Barlow, Muthmann, Tutton, Sollas, Goldschmidt, Viola, and others.

it was determined to introduce one pound of Fluorescein into the open joint down which the water was flowing.

This was done at 2 P.M. on November 11, and before 7 A.M. on the 12th the water of the large spring at the reservoir in the Greta Valley was strongly coloured.

After introducing the Fluorescein a general survey was made of the direction of the joints in the limestone in the neighbourhood of the sink and on the clints above Crina Bottom, with the following results :—

Joint at 'sink'	N. 55° W.
On 'clints' near sink	N. 5° W.
On 'clints' above and to the west of Crina Bottom	(main) N. 50° W. (secondary) S. 25° W.

The spring at the reservoir is thrown out close to the line of junction of the Carboniferous Limestone with the underlying Silurian rocks, and the line from the sink where the Fluorescein was introduced to the spring runs N. 55° W.—that is, in the direction of the master joints in the limestone.

Thus, again, it has been demonstrated that the direction of underground flow is determined by that of the master joints in the limestone.

After a considerable though unavoidable delay the work was resumed on June 21, 1901, when Alum Pot, on the Ribblesdale side of Ingleboro', was the scene of operations.

The joints in the neighbourhood of Alum Pot are more complicated than in the parts of the district previously investigated, there being three sets of joints, all more or less irregular in places.

Close to Alum Pot there are two sets running S. 5° W. and N. 80° E. respectively.

Thirty yards higher up Alum Pot Beck they run due N. and S. and N. 80° E., the north and south joints being the stronger and more continuous.

On the 'clints' 100 yards above the Pot there are three sets of joints, as follows, viz.—

Master	N. 10° E.
Secondary.	N. 35° E. N. 85° E.

One pound of Fluorescein was put into the stream flowing into Alum Pot on Friday, June 21, at 7 P.M.

There was not much water flowing at the time, and a few days afterwards several important springs in the neighbourhood ran dry, including that at Turn Dub, on the opposite bank of the Ribble, which is the reputed outlet of the Alum Pot stream.

The springs commenced to flow again a few days later ; but although they were carefully watched, as was also the river itself, no trace of colour was seen.

It was therefore concluded that either the Fluorescein had passed into one of the other river basins or had become so diluted as to be invisible.

This experiment having proved inconclusive, a further one was commenced on Thursday, September 5, the results of which are not yet known.

Owing to the long delay caused by the drought and other circumstances beyond their control, the Committee have been unable to

complete the work during the present year, and therefore ask to be reappointed and to be allowed to retain the unexpended balance of the grant made at the Bradford meeting.

Photographs of Geological Interest in the United Kingdom.—Twelfth Report of the Committee, consisting of Professor JAMES GEIKIE (*Chairman*), Dr. T. G. BONNEY, Professor E. J. GARWOOD, Dr. TEMPEST ANDERSON, Mr. GODFREY BINGLEY, Mr. H. COATES, Mr. C. V. CROOK, Mr. J. G. GOODCHILD, Mr. WILLIAM GRAY, Mr. ROBERT KIDSTON, Mr. A. S. REID, Mr. J. J. H. TEALL, Mr. R. WELCH, Mr. H. B. WOODWARD, Mr. F. WOOLNOUGH, *and* Professor W. W. WATTS (*Secretary*). (*Drawn up by the Secretary.*)

THE Committee have the honour to report that during the year 241 new photographs have been received, bringing up the total number in the collection to 2,896.

In addition to this 3 prints and 3 slides have been given to the duplicate collection, making a total of 247 photographs received during the year.

A scheme showing the geographical distribution of the photographs is appended. There are no new counties on the list, but the following counties are now much better represented than hitherto :—Cumberland, Derby, Durham, Lincoln, Norfolk, Northumberland, Wiltshire, and Pembroke. Cambridgeshire continues to share with Rutland and Huntingdon the distinction of being unrepresented in the collection. There are three Welsh counties unrepresented, eleven in Scotland, and fourteen in Ireland. As Brecknock, Dumbarton, Ross-shire, Wicklow, Kilkenny, and Waterford are amongst these counties it is evident that the work of the Committee cannot yet be considered complete.

To this year's collection the most noteworthy accession is Dr. G. Abbott's set of photographs of sections and specimens illustrating his study of the remarkable concretionary structures exhibited by the Magnesian Limestone of Durham.

Another important contribution is a beautiful series of views illustrating problems on Physical Geography and Geology in the Cheviots, taken by Mr. G. Bingley and Mr. Hastings. The former also sends photographs from Yorkshire.

Mr. Coomára-Swámy has taken photographs in Lakeland and Wiltshire, and Mr. Monckton in Dorset, Surrey, and Berkshire.

Mr. A. T. Metcalfe contributes an interesting series of glacial photographs from the Norfolk coast, and a set illustrating the volcanic vents of Derbyshire recently described by Sir Archibald Geikie.

The Hull Geological Society and the Croydon Microscopical and Natural History Club send some local photographs, and the members of the North Staffordshire Field Club also continue their contributions.

Mr. Jerome Harrison sends some exceptionally beautiful and interesting pictures of drift deposits and of striated boulders, of glacial phenomena about Snowdonia, and of surface creep. He also sends illustrations of Palæozoic and pre-Palæozoic rocks in the Midlands, while the Uriconian rocks of Shropshire have been photographed by Mr. Buddicom as well.

—	Previous collection	Additions (1900)	Total	Duplicates: Previous collection	Duplicates: Additions (1900): Prints	Duplicates: Additions (1900): Slides	Duplicates: Total
ENGLAND—							
Berkshire .	3	2	5	—	—	—	—
Cumberland .	8	10	18	—	—	—	—
Derbyshire .	30	11	41	1	—	—	1
Devonshire .	126	9	135	13	2	2	17
Dorset . .	90	9	99	8	—	—	8
Durham . .	29	82	111	1	—	—	1
Kent . .	70	2	72	13	—	—	13
Lincolnshire .	4	2	6	—	—	—	—
Norfolk . .	18	5	23	7	—	—	7
Northumberland . .	42	28	70	—	—	—	—
Nottinghamshire . .	13	1	14	1	—	—	1
Shropshire .	33	11	44	8	1	—	9
Staffordshire .	42	9	51	10	—	—	10
Surrey . .	35	8	43	3	—	—	3
Sussex . .	10	2	12	—	—	—	—
Warwickshire .	36	2	38	3	—	—	3
Westmoreland.	61	1	62	6	—	—	6
Wiltshire .	1	4	5	—	—	1	1
Worcestershire	14	5	19	1	—	—	1
Yorkshire .	446	10	456	67	—	—	67
Others . .	388		388	59	—	—	59
Total . .	1499	213	1712	201	3	3	207
WALES—							
Carnarvon .	74	18	92	24	—	—	24
Pembroke .	12	3	15		—	—	—
Others . .	87	—	87	19	—	—	19
Total . .	173	21	194	43	—	—	43
CHANNEL ISLANDS . .	15	—	15	—	—	—	—
ISLE OF MAN .	60	—	60	4	—	—	4
SCOTLAND—							
Inverness .	114	1	115	32	—	—	32
Others . .	196	—	196	49	—	—	49
Total . .	310	1	311	81	—	—	81
IRELAND—							
Donegal . .	44	1	45	3	—	—	3
Others . .	463	—	463	55	—	—	55
Total . .	507	1	508	58	—	—	58
ROCK STRUCTURES, &c .	91	5	96	31	—	—	31
FOREIGN .	—	—	—	29	—	—	29

—	Previous collection	Additions (1900)	Total	Duplicates			
				Previous collection	Additions (1900)		Total
					Prints	Slides	
England	1499	213	1712	201	3	3	207
Wales	173	21	194	43	—	—	43
Channel Islands	15	—	15	...	—	—	—
Isle of Man	60	—	60	4	—	—	4
Scotland	310	1	311	81	—	...	81
Ireland	507	1	508	58	—	—	58
Rock Structures	91	5	96	31	—	—	31
Foreign	—	—	—	29	—	—	29
Total	2655	241	2896	447	3	3	453

To these gentlemen and to the contributors mentioned below the Committee tender their thanks: Professor W. Hillhouse, Professor E. J. Garwood, Mr. J. H. Baldock, Mr. W. S. Parrish, Mr. J. A. Cossins, the Rev. C. F. L. Barnwell, Mr. H. J. Steele, Mr. F. W. Roberts, Mr. W. B. Bannerman, Miss M. S. Johnston, Mr. J. W. Stather, Mr. Watson, Miss M. K. Andrews, and Mr. W. W. Midgley.

The Committee notice an increasing tendency on the part of contributors to send in enlarged photographs. If the enlargement shows details not easily visible on the originals, and if they are sharp and clear, this is an excellent thing. But unless this is the case enlargements do not appear to possess any advantage over the smaller photographs; indeed, rather the reverse; while they occupy considerably more storage room. 'Fuzzitypes' have no precise functions in illustrating geological phenomena.

The Committee would again call attention to the insertion of a scale whenever possible into the photographs—not an ordinary foot-rule the divisions of which are invariably invisible, but something of average size which cannot be easily mistaken—the human figure, a walking-stick, camera-case, hat, pencil, or coin.

The additions to the duplicate collection number only six. Several others are in hand; but it is thought advisable to hold them back for a time in order to get complete sets on certain subjects.

The duplicate collection has been sent to Natural History Societies at the following places:—Dulwich College, Halifax, Haslemere, Highgate, Accrington, and Woking.

The little set of photographs which was framed for exhibition at Paris in 1900 is now displayed in the Museum of Practical Geology at Jermyn Street. The silver medal awarded to it, or rather the bronze copy thereof, will doubtless be received at some future time.

The scheme for publishing a selection of typical geological photographs is progressing, in spite of a series of unforeseen delays. The first batch of twenty-two prints and slides will shortly be issued, and the preparation of the second and third batches will be proceeded with.

Applications by local societies for the loan of the duplicate collection should be made to the Secretary. Either prints or slides, or both, can be

Regd. No.		
2745	( ) Thurlestone Sands, W. of Kingsbridge.	Outlier of New Red Sandstone resting unconformably on Slates of the Torcross Group. 1901.
2746	( ) Thurlestone Sands, W. of Kingsbridge.	Outlier of New Red Sandstone. 1901.
2747	( ) Thurlestone Sands, W. of Kingsbridge.	" " "
2748	( ) Thurlestone Sands, W. of Kingsbridge.	" " "

DORSET.—*Photographed by* H. W. MONCKTON, *F.G.S.*, 3 *Harcourt Buildings, Temple, E.C.* 1/1 E.

2672	(1896) Durlstone Bay, Swanage	Middle Purbeck Stone Beds. 1900.
2673	(1897) " " "	" " " "
2674	(1410) Near Grand Hotel, Swanage Bay.	Wealden Beds. 1900.
2675	(1420) Punfield Cove, Swanage	Shell-bed of *Pecten asper* zone of Upper Greensand. 1900.
2676	(1421) " " "	Shell-bed of *Pecten asper* zone of Upper Greensand. 1900.
2677	(1439) Tilly Whim 'Caves,' Swanage.	Block of Portland Oyster Bed. 1900.
2678	(1426) West Hill and St. Alban's Head, above Chapman's Pool.	Portland Stone, Sand, and Kimeridge Clay. 1900.
2679	(1427) Cliff, E. of St. Alban's Head.	Portland Stone and Sand, over Kimeridge Clay. 1900.
2680	(1449) The Agglestone, near Studland.	Concretionary Sand-rock weathered out of Bagshot Beds. 1900.

See also DURHAM.

DURHAM.—*Photographed by* Dr. G. ABBOTT, 33 *Upper Grosvenor Road, Tunbridge Wells. Three by* Messrs. JOHNSON *and* BIRD, *Tunbridge Wells.* 1/2 *and* 1/4.

2749	(14) Fulwell Quarry, near Sunderland.	Section of Magnesian Limestone, showing concretionary structure. 1900.
2750	(15) Hendon Shore . . .	Deposition partings in concretions. 1900.
2751	(16) Hendon Shore (some in British Museum).	Finger-like rods. 1900.
2752	(17) Fulwell	Rods and some honeycombs. 1900.
2753	(18) Building Hill, Sunderland.	Rod structure. 1900.
2754	(19) Building Hill, Sunderland.	Large spherical concretion. 1901.
2755	(1078) (In British Museum)	Rods coated with crystals "
2756	(1072) " " .	Rod structure. "
2757	(1147) " " .	Rods on each side of band. "
2758	(1084) " " .	Rods, short and thick. "
2759	(988) Fulwell	Rods grown downwards. 1900.
2760	(989) "	Rods grown upwards. "
2761	(990) "	Rods grown horizontally from cleavage clefts. 1900.
2762	(987) "	Nodes on rods.
2763	(20) Hendon Shore . . .	'Honeycomb.' 1900.
2764	(21) Fulwell Quarry . . .	" 1899.
2765	(22) Hendon Shore . . .	" 1900.
2766	(23) Building Hill, Sunderland.	" "
2767	(24) Fulwell Quarry . . .	Honeycomb. 1901.
2768	(25) " "	" 1900
2769	(26) " "	" "
2770	(27) " "	" "
2771	(28) " "	" "

Regd. No.		
2772	(29) Fulwell Quarry . .	
2773	(11 & 12) Hendon . . .	Honeycomb, cut and uncut surface. 1901.
2774	(2) Fulwell	Honeycomb, showing conical nodes. 1900.
2775	(30) (Hancock Museum, Newcastle)	Honeycomb and 'cauliflower' concretion. 1900.
2776	(992) Fulwell (British Museum)	Honeycomb. 1901.
2777	(1003) ,, ,, ,,	,, ,,
2778	(991) ,, ,, ,,	,, ,,
2779	(1027) ,, ,, ,,	,, ,,
2780	(1091) Fulwell	,, ,,
2781	(1128) ,, ...	,, ,,
2782	(1088) ,, ...	,, ,,
2783	(1046) ,, ...	,, ,,
2784	(1131) ,, ...	,, ,,
2785	(1130) ,, ...	,, ,,
2786	(1097) Fulwell (British Museum)	,, ,,
2787	(1099) ,, ,, ,, .	,, ,,
2788	(1050) ,, ,, .	,, ,,
2789	(1051)	,, ,,
2790	(1136)	,, ,,
2791	(993) Fulwell	,, ,,
2792	(1029) Fulwell (British Museum)	,, ,,
2793	(998) Fulwell	,, ,,
2794	(999) Fulwell (British Museum)	,, ,,
2795	(1032) ,, ,, ,,	,, ,,
2796	(1035) ,, ,, ,,	,, ,,
2797	(31) Fulwell.	,, see 2767. 1900.
2798	(1) Fulwell (British Museum) .	Coralloid. ,,
2799	(32) Fulwell	,, Ripple-marked. ,,
2800	(3) ,, ...	,, ,,
2801	(1048) Fulwell (British Museum)	,, ,,
2802	(1004) ,, ,, ,,	,, ,,
2803	(1083) ,, ,, ,,	,, ,,
2804	(1082) ,, ,, ,,	,, see 2803. ,,
2805	(1052) ,, ,, ,,	,, ,,
2806	(996) Fulwell	,, ,,
2807	(1098) Fulwell (British Museum)	,, ,,
2808	(1045) ,, ,, ,,	,, ,,
2809	(1149) Fulwell	,, ,,
2810	(1101) ,, ...	,, ,,
2811	(1123) ,, ...	,, ,,
2812	(1144) ,, ...	,, ,,
2813	(1100) Fulwell (British Museum)	,, ,,
2814	(1077) ,, ,, ,,	,, ,,
2815	(1102) Fulwell	Coralloid, segregation bands. 1901.
2816	(1092) Fulwell (British Museum)	,, ,, ,, ,,
2817	(1135) Fulwell	Coralloid, see 2799. ,,
2818	(1140) ,, ...	Honeycomb, to show cleavage across rods. 1901.
2819	(1142) ,, ...	Primary bands and rods. 1900.
2820	(994) Fulwell (British Museum)	Banding of honeycomb and primary banding. 1900.
2821	(995) Weymouth, Dorset (Two in British Museum).	Segregation bands in mortar. 1899.
2822	(100) Wall of Bamburgh Castle, Northumberland.	,, ,, ,, ,,
2823	(33) Fulwell	Pseudo-organic structure, 1900.
2824	(34) ,, ...	,, ,, ,,
2825	(35) Parson's Rock, Roker	Cannon-ball bed. 1899.
2826	(36) (British Museum) .	Egg and balls, single and compound. 1899.

Regd. No.		
2827	(37) Fulwell	Botryoidal masses, some with 'undercoat banding.' 1900.
2828	(38) "	Botryoidal masses, some with 'undercoat banding.' 1900.
2829	(39) "	Mass of balls. 1900.
2830	(40) Hendon Shore . . .	Balls and bands in alternate layers. 1900

KENT.—*Photographed by* J. H. BALDOCK, *Overdale, St. Leonard's Road, Croydon. Sent through the Croydon Microscopical and Natural History Club.* 1/2.

2681	(3) Gravel pit north of railway, Shortlands.	Oldhaven Pebble Beds. 1899.
2682	(4) Gravel pit north of railway, Shortlands.	" " " "

LINCOLNSHIRE.—*Photographed by* W. S. PARRISH, 2 *Waltham Street, Hull. Sent through the Hull Geological Society.* 1/1 E.

2877	(18) ¾ m. from Frodingham Railway Station.	Lower Lias, Frodingham Ironstone, with overlying beds of peat and gravel. 1898.
2878	(19) ¾ m. from Frodingham Railway Station.	Lower Lias, Frodingham Ironstone, with overlying beds of peat and gravel. 1898.

NORFOLK.—*Photographed by* A. T. METCALFE, *F.G.S., Southwell, Notts.* 1/4.

2683	(G 15) Cliff between West Runton & Sherringham.	Contorted Drift. 1900.
2684	(G 16) Cliff between West Runton and Sherringham.	Contorted Drift and Glacial Sands. 1900.
2685	(G 17) Cliff between West Runton and Sherringham.	Contortions in Glacial Sands and Gravels. 1900.
2686	(G 18) Cliff just E. of Sherringham.	Contorted Drift. 1900.
2687	(G 21) Norwich . . .	House occupied by Professor Sedgwick when Canon of Norwich. 1900.

NORTHUMBERLAND.—*Photographed by* G. BINGLEY, *Thorniehurst, Headingley, Leeds.* 1/2.

2688	(5275) Shining Pool, Harthope Burn, near Wooler.	Lateral Moraine. 1900.
2689	(5276) Below Shining Pool .	Andesite Hills, with Hedghoppe in background. 1900.
2690	(5277) From Shining Pool .	Moraine material, containing blocks from the Tweed Valley. 1900.
2691	(5280) Cheviot from Langleeford.	Junction of Granite and Porphyrite. 1900.
2692	(5282) Housey Crag, Langleeford.	Fresh Andesite, resting on Porphyrite. 1900.
2693	(5290) South Bank of Harthope Burn, Langlee.	Junction of Granite and metamorphosed Porphyrites. 1900.
2694	(5291) ¾ m. west of Calder Farm.	Overflow valley of glacial lake of the Breamish. 1900.
2695	(5292) Near confluence of Greenside Burn and R. Breamish, near Ingram.	Porphyrites. 1900.
2696	(5293) Near confluence of Greenside Burn and R. Breamish, near Ingram.	Porphyrites with talus slopes ('glitters'). 1900.

Regd. No.		
2697	(5295) River Till, near Wooler .	Foreground of Lower Carboniferous Rocks and Andesite Hills of Cheviot in distance. 1900.
2698	(5297) near Akeld Burn, S. of White Law.	Overflow valley into Akeld Burn. 1900.
2699	(5299) Munday Cleugh, near Wooler.	Overflow valley of a glacial lake. 1900.
2700	(5300) Humbleton Hill, near Wooler.	Dry gorge, the overflow of a glacial lake. 1900.

Photographed by G. HASTINGS, 15 *Oak Lane, Bradford.* 1/2.

2831	(171) Cheviots from Tom Tolton's Crag, near Wooler.	General View. 1900.
2832	(173) View across Wooler Burn.	Dry valley behind Humbleton. 1900.
2833	(168) Wooler Burn, S. of Black Law.	1900.
2834	(172) Golf Links, near Wooler .	Two streamless rock-gorges. 1900.
2835	(169) Near Wooler . . .	Dry valley. 1900.
2836	(167) Yeavering Bell, near Wooler.	Dry watercourse. 1900.
2837	(163) Roddam Dene, near Wooler.	Post-Glacial gorge in Carboniferous conglomerate. 1900.
2838	(162) West side of Akeld Burn, above Gleadscleugh, near Wooler.	Deep channel. 1900.
2839	(161) From Humbleton Hill, near Wooler.	System of dry gorges. 1900.
2840	(158) Shining Pool, near Wooler.	Ridges and dry valleys. 1900.
2841	(157) " " .	Dry valley above pool. 1900.
2842	(164) Linhope Burn . . .	Jointed Augite-granite. 1900.
2843	(156) Harthope Burn, above Langleeford.	Granite, veined with tourmaline. 1900.
2844	(152) Housey Crag, Langleeford.	Fresh Andesite. 1900.
2845	(151) Junction of Harthope Burn and Carey Burn.	Cheviot Porphyrites. 1900.

NOTTINGHAM.—*Photographed by* E. A. BUSH, *Engineer's Department, Guildhall, Nottingham, and contributed by* J. SHIPMAN, *F.G.S.*

2879	( ) Hemlock Stone . . .	Stack of New Red Sandstone cemented by Barytes. 1899.

SHROPSHIRE.—*Photographed by* R. A. BUDDICOM, *M.A., F.G.S., The Museum, Plymouth.* 1/2.

2639	( ) Caer Caradoc, from east slope of Helmeth.	General view of folding. 1899.
2640	( ) Caer Caradoc . . .	Synclinal fold in Uriconian Rocks. 1899.
2641	( ) " . . .	" " "
2642	( ) " . . .	" " "
2643	( ) Caer Caradoc and part of Hope Bowdler Hill.	Uriconian Rocks. 1899.
2644	( ) Caradoc, &c., from the Burway on the Longmynd.	The Uriconian Chain. 1899.
2645	( ) View from halfway between Wall's Bank and Hope Bowdler.	Clee Hills, Wenlock Edge, &c. 1900.
2646	( ) Near Dorrington Station, near Shrewsbury.	Two Boulders of grey (? Eskdale) Granite. 1900.

Photographed by W. JEROME HARRISON, *F.G.S.*, 52 *Claremont Road, Handsworth, Birmingham*, 1/2.

Regd. No.			
2658	( )	Near top of Caer Caradoc .	Brecciated Rhyolite. 1897.
2659	( )	The Lawley, from Comley Quarry.	Uriconian Rocks. 1897.

Photographed by J. A. COSSINS, *Forster Road, Moseley, Birmingham.* 5/4.

2846	( )	Barrow, near Broseley .	Fossil tree in Coal-measures. 1901.

STAFFORDSHIRE.—*Photographed by* W. JEROME HARRISON, *F.G.S.*, 52 *Claremont Road, Handsworth, Birmingham.* 1/2.

2647	( )	Railway cutting, Aldridge .	Coral mass in Wenlock Shale. 1900.
2648	( )	" "	Fossiliferous Wenlock Shale. 1900.
2649	( )	" "	" " "
2650	( )	" "	" " "

Photographed by Rev. C. F. L. BARNWELL, *Stramshall Vicarage, Uttoxeter. Sent through the North Staffordshire Field Club.* 1/2.

2847	(9)	The Common Plot, Stone .	Artificial Caves in Keuper Sandstone. 1901.
2848	(10)	" "	" " "
2849	(12)	" "	Ripple-marking on roof of 'caves.' 1901.
2850	(11)	" "	" " "

Photographed by H. J. STEELE, *Barton House, Burslem. Sent through the North Staffordshire Field Club.* 5/4.

2851	(8)	Beggar's Well Quarry, near Alton.	Faulted Triassic Sandstone. 1899.

SURREY.—*Photographed by* H. W. MONCKTON, *F.G.S.*, 3 *Harcourt Buildings, Temple, E.C.* 1/1 E.

2701	(985)	Tadworth Railway Cutting	Drift resting irregularly on Thanet Sands. 1898.
2702	(987)	" "	Thanet Sand on Chalk. 1898.
2703	(1472)	Godstone, W. of main road in village.	Folkestone Beds in Lower Greensand. 1900.
2704	(1473)	Godstone, W. of main road in village.	" " "

Photographed by F. W. ROBARTS, 23 *Oliver Grove, South Norwood, S.E. Sent through the Croydon Microscopical and Natural History Club.* 1/1 E.

2705	(1)	Addiscombe Road, Croydon .	Blackheath and Oldhaven Beds overlying Ostrea Bed. 1898.

Photographed by W. B. BANNERMAN, *F.G.S.*, *Sydenham Road, Croydon. Sent through the Croydon Microscopical and Natural History Club.* 1/1 E.

2706	(2)	Seneca Road and Bensham Lane, Thornton Heath.	Sandstone Boulders at bottom of gravel pit, resting on London Clay. 1899.

Photographed by J. H. BALDOCK, *Overdale, St. Leonard's Road, Croydon. Sent through the Croydon Microscopical and Natural History Club.* 1/1 E.

Regd. No.			
2707	(5)	Whyteleafe Chalk Pit . .	Lower part of Upper Chalk and Middle Chalk. 1899?

Photographed by Miss MARY S. JOHNSTON, *Hazelwood, Wimbledon Hill, Surrey.* 1/4.

2852	(10)	Quarry north of Godstone .	Lower bed of sand in Folkestone Beds. 1900.

SUSSEX.—*Photographed for* W. W. WATTS, *Birmingham University.* 1/1 *and* 1/2.

2853	( )	East of Seaford . . .	Valley in Chalk-Downs, illustrating subaërial topography. 1898.
2854	( )	Near mouth of R. Cuckmere	Chalk Cliffs; destruction of subaërial topography by the sea. 1898.

WARWICKSHIRE.—*Photographed by* W. JEROME HARRISON, *F.G.S., 52 Claremont Road, Handsworth, Birmingham.* 1/2.

2651	( )	Blackroot Pool, Sutton Park	Fault in Trias. 1900.
2657	( )	Temple Grafton, N.W. of Stratford-on-Avon.	Scarp of Rhaetic Rocks. 1900.

WESTMORELAND.—*Photographed by* A. K. COOMÁRA-SWÁMY, *B.Sc., F.G.S., Worplesdon, Guildford.* 1/4.

2865	( )	South side of Dunmail Raise	Moraine mounds. 1900.

WILTSHIRE.—*Photographed by* A. K. COOMÁRA-SWÁMY, *B.Sc., F.G.S., Worplesdon, Guildford.* 1/4.

2856	( )	Fields, ½ m. N.E. of Place Farm, Tisbury.	Scenery in the Vale of Wardour. 1900.
2857	( )	Ladydown, near Tisbury .	Middle Purbeck Rocks. 1900.
2858	( )	Chilmark Ravine, west side	Upper Portland 'Lower building Stones.' 1900.
2859	( )	,, ,, east side	Upper Portland, 'Chalky Series.' 1900.

WORCESTER. *Photographed by* W. JEROME HARRISON, *F.G.S., 52 Claremont Road, Handsworth, Birmingham.* 1/2.

2652	( )	Wren's Nest, Dudley . .	General view of Silurian inlier. 1900.
2653	( )	,, ,,	Curved strike of Wenlock Shales. 1900.
2654	( )	The Lickey Hills, seen from Rubery.	Cambrian Quartzite, flanked by Llandovery Sandstone. 1900.
2655	( )	Rednall Gap and Bilberry Hill, The Lickeys.	Cambrian Quartzite. 1900.
2656	( )	Bilberry Hill	Overfolded Cambrian Quartzite. 1900.

YORKSHIRE.—*Photographed by* GODFREY BINGLEY, *Thorniehurst, Headingley, Leeds.* 1/1 E.

2860	(5346)	Garforth	Lower Magnesian Limestone. 1900.
2861	(5347)	,, ...	,, ,, ,,

Regd. No.		
2862	(5348) Micklefield . . .	Magnesian Limestone. 1900.
2863	(5349) " . . .	" "
2864	(5350) " . . .	Piped surface of Magnesian Limestone. 1900.
2865	(5352) Meanwood Valley, Leeds.	Folded Gannister beds. 1900.
2866	(5351) " "	Stigmaria in Gannister Sandstone. 1900.
2867	(5338) Draughton Quarry, near Skipton.	Folded, brecciated, and overthrust Carboniferous Limestone. 1900.
2868	(5340) Draughton Quarry . .	Folded, brecciated, and overthrust Carboniferous Limestone. 1900.

Photographed by J. W. STATHER, 224 *Spring Bank, Hull. Sent through the Hull Geological Society.* 1/1 E.

2876	(20) Cliffs near Skipsea . .	Chalk embedded in Boulder-clay, crushed by glacial action. 1900.

CARNARVON.—*Photographed by* W. JEROME HARRISON, *F.G.S., 52 Claremont Road, Handsworth, Birmingham.* 1/2.

2708	( ) Conway Mountain and Penmaenmawr, from Diganwy.	Intrusive felsites and diorites. 1900.
2709	( ) Great Orme's Head, from Diganwy.	Boulder-clay and Carboniferous Limestone. 1900.
2710	( ) Diganwy Shore . . .	Cliff of Black Boulder-clay. 1900.
2711	( ) "	Cliff of Boulder-clay. 1900.
2712	( ) "	Cliff of Black Boulder-clay. 1900.
2713	( ) "	" " " "
2714	( ) "	Striated Boulder *in situ* in Boulder-clay. 1900.
2715	( ) "	Cliff of Boulder-clay and boulders washed out of it. 1900.
2716	( ) "	Large Scratched Boulder. 1900.
2717	( ) "	" " " "
2718	( ) Snowdon, from Bwlch Main	Bala volcanic ash. 1900.
2719	( ) Bwlch Main, Snowdon .	Bala slaty rocks. 1900.
2720	( ) Cwm Glas, from the Pass of Llanberis.	Moraine and Perched Blocks. 1900.
2721	( ) Cwm Glas, from the Pass of Llanberis.	Moraine. 1900.
2722	( ) Cwm Glas, from the Pass of Llanberis.	" "
2723	( ) Cwm Glas, from the Pass of Llanberis.	Moraine, near view. 1900.
2724	( ) Pass of Llanberis, looking up, near Pont-y-Gromlech.	*Roches moutonnées*, 'Lee-seite,' 1900.
2725	( ) Pass of Llanberis, looking down near Pont-y-Gromlech.	Crags and Screes of Esgair Felen. 1900.

PEMBROKESHIRE.—*Photographed by* W. JEROME HARRISON, *F.G.S., 52 Claremont Road, Handsworth, Birmingham.* 1/1.

2660	( ) South of Whitesand Bay .	Terminal curvature in Cambrian Slates. 1897.

Photographed by C. J. WATSON, *Botville Road, Acock's Green, Birmingham.* 1/2.

2726	(916) Stack Rocks, Tenby. .	Marine erosion in Carboniferous Limestone. 1899.
2727	(969) Old Quarry face, Tenby .	*Productus* in Carboniferous Limestone. 1899.

SCOTLAND.

INVERNESS.—*Photographed by* A. K. COOMÁRA-SWÁMY, *B.Sc., F.G.S., Worplesdon, Guildford.* 1/4.

Regd. No.

2869 ( ) Near Sgur-a-Marbhaid . Block of contorted Lewisian Gneiss. 1899.

IRELAND.

DONEGAL.—*Photographed by* Miss M. K. ANDREWS, 12 *College Gardens, Belfast.* 12/10 E.

2870 (70) Mullaghdlerg, Inishfree Bay Spheroidal Granite. 1900.

ROCK STRUCTURES, &c.

Photographed by A. K. COOMÁRA-SWÁMY, *B.Sc., F.G.S., Worplesdon, Guildford.* 1/4.

2871 ( ) Glenderaterra, Cumberland; and Brittany. Specimens of Chiastolite-slate. 1900.

Photographed by W. W. MIDGLEY, *The Museum, Bolton.* 1/4.

2872 (56) Arthur's Seat, Edinburgh . Olivine-basalt. × 20.
2873 (55) Sudbury, Ontario . . Olivine-diabase. × 18.
2874 (52) Bertoon, Banff . . . Pegmatite. × 20.
2875 (11) Armboth Fell, Cumberland . Quartz-porphyry. × 30.

See also under Durham.

LIST II.

THE DUPLICATE (LOAN) COLLECTION.

The numbers placed after the description of the photograph refer to the list of photographers, whose names and addresses are given at the end.

Full localities and descriptions are given in List I. under the numbers.

This collection is arranged geologically, and from time to time the less perfect and less typical photographs will be removed and better ones substituted as they are given. Those laid aside can always be seen, sent, or returned by request.

* Indicates that prints and slides may be bought from the photographer. P. indicates prints. S. indicates slides.

Rock Structures.

Fossils in Rocks.

2846 Fossil Tree in Coal-measures . Barrow, Broseley, Shropshire. 61 P.

Evidences of Earth-movement.

Folding.

2740 Anticline . . . . Near Wildersmouth Beach, Ilfracombe, Devon. 60 P.S.

Surface Agencies: Denudation and Deposit.

Marine Action: Denudation.

2741 Marine Pothole . . . . Ilfracombe, Devon. 60 P.S.

Characteristic Rocks and Landscapes.

Mesozoic.

2857 Middle Purbeck Rocks . . Ladydown, near Tisbury. 40 S.

Names and Addresses of Donors and Photographers.

40. A. K. Coomára-Swámy, Walden, Worplesdon, Guildford.
60. Professor W. Hillhouse, The University, Birmingham.
61. J. A. Cossins, Forster Road, Moseley, Birmingham.

Ossiferous Caves at Uphill.—Report of the Committee, consisting of Professor C. LLOYD MORGAN (*Chairman*), Mr. H. BOLTON (*Secretary*), Professor W. BOYD DAWKINS, Mr. W. R. BARKER, Mr. S. H. REYNOLDS, *and* Mr. E. T. NEWTON, *appointed for the purpose of excavating the Ossiferous Caves at Uphill, near Weston-super-Mare.*

THE Committee have to report that no further progress has been made since last September. Quarrymen in the ordinary course of their duties have continued to cut back the rock face for road material. The fissure caves first excavated are now in large part destroyed, but little of interest was found. Visits have been paid by the local members of the Committee on several occasions in the hope of locating a new deposit, but none could be found to justify working.

The chief find of interest during the year has been that of a badger skull, in good condition. The badger is native to the country, the last specimen in the Uphill district having been killed about twelve years ago. The present skull seems, however, to have been contemporaneous with the cave animals.

A well developed tooth of Elephas and two portions of a fine tusk were picked up by the quarrymen.

Professor Reynolds has continued his examination of the cave material, and will publish his observations later.

The Committee, finding no site was promising enough to work, did not draw the grant of 5*l.* made last year. The Committee do not ask for reappointment.

The Zoology of the Sandwich Islands.—Eleventh Report of the Committee, consisting of Professor NEWTON (*Chairman*), Dr. W. T. BLANFORD, Professor S. J. HICKSON, Mr. F. DU CANE GODMAN, Dr. P. L. SCLATER, Mr. E. A. SMITH, *and* Mr. D. SHARP (*Secretary*).

SINCE the last report Mr. R. C. L. Perkins has been maintained by the Committee at his work in the islands, and it is intended that he shall remain there for a few months longer, after which the funds of the Com-

mittee available for this purpose will be exhausted. He has been working almost solely on the island of Oahu, where zoological devastation is taking place both extensively and rapidly.

Seven parts of the 'Fauna Hawaiiensis' have now been published, and two more are in the press. The part published since the last report is devoted to *Coleoptera*, and was prepared by Mr. Perkins while in this country, and by the Secretary of the Committee.

It is hoped that Mr. Perkins' services may be secured after his return to this country with the object of completing the 'Fauna Hawaiiensis.'

The Committee asks for reappointment with the same powers as before and a grant of 50*l*.

Plankton and Physical Conditions of the English Channel, 1899–1900.—*Interim Report of the Committee, consisting of* Professor E. RAY LANKESTER (*Chairman*), Mr. W. GARSTANG (*Secretary*), Professor W. A. HERDMAN, *and* Mr. H. N. DICKSON. (*Drawn up by the Secretary.*)

THE analysis of the numerous collections of Plankton made during the periodic cruises in 1899–1900 is now approaching completion.

Owing to the many disadvantages of the counting method introduced by Hensen an attempt has been made to utilise the method of graded filtration in the quantitative analysis of the vertical hauls, the mass of each 'grade' being determined volumetrically. Five grades have been selected, which correspond in general with the following dominant types of the plankton :—(1) Medusoids, (2) Calanus, (3) small Copepods, (4) Larvæ, (5) Diatoms and Cilioflagellates. The largest grade is that determined by a square mesh whose side is 1·5 mm. long ; the next by a mesh 1 mm. square. These dimensions are approximately realised in bolting silk ('miller's gauze') having sixteen and twenty-six threads to the inch respectively. The following table gives the complete series of standard filters adopted :—

Grade	No. of Threads per Inch	No. of threads per cm.
A	16	6–7 (6 meshes)
B	26	10
C	50	20
D	100	40
E	150	60

It is found that the errors which attend the volumetric method when applied to plankton samples consisting of mixed and varied constituents are greatly reduced by the preliminary process of separation into definite grades of size ; and it is hoped that a thorough trial of this method of analysis may result in its establishment as an efficient method for the quantitative comparison of plankton of different localities and seasons, in conjunction with the method of vertical hauls introduced by Hensen.

The Committee respectfully request their reappointment for one year longer, without a grant, in order that they may present a summary of the results to the next Meeting of the Association.

Occupation of a Table at the Zoological Station at Naples.—Report of the Committee, consisting of Professor W. A. HERDMAN (*Chairman*), Professor E. RAY LANKESTER, Professor W. F. R. WELDON, Professor S. J. HICKSON, Mr. A. SEDGWICK, Professor W. C. McINTOSH, *and* Professor G. B. HOWES (*Secretary*).

THE work of the year has been of the steadily progressive order which marks progress. Mr. H. H. Stewart, for whom appeal was made, was at the last moment prevented by college duties from fulfilling his desire. Capable investigators were, however, forthcoming in Dr. Reginald Buller, of Munich, and Dr. Hamlyn-Harris, also at present working on the continent. These gentlemen, in availing themselves of the opportunity of study which the Association afforded, have accumulated material sufficient for long-continued research.

In a letter received by your Committee from Dr. Anton Dohrn special acknowledgment is given, on behalf of himself and the associated members of his staff, of the terms in which, in the Association's Report for 1900, their work has been described. He desires that the best thanks of all be conveyed through your Committee to the officers and members of the Association for their confidence and support, with the assurance that it has done much to encourage them in their conviction that the requirements of marine biological study are as great as those of the terrestrial order, and that both should be equally maintained and equipped.

Under this resolve, efforts are now being made at Naples to develop the experimental and more strictly physiological side of the work in hand. It is needless to insist on the advantages which must accrue from the study of the rich fauna of the Neapolitan marine area to the largely open field of comparative physiology. Work of the experimental type is now revolutionising certain branches of biological inquiry, and in deciding to keep pace with this, those in charge of the Naples establishment are to be commended.

To the resolve of Dr. Dohrn and his associates your Committee acquiesce, and they, with increased assurance, recommend the claim of the Naples Station for continued support to your consideration. It has been in the direction for which encouragement is now sought that both occupants of the Association's table have during the past year been engaged—Dr. Buller's work having been more especially of a most advanced order—and it is accordingly with the greater satisfaction that your Committee, in applying for a renewal of the grant, do so to enable Mr. R. Gurney, of

Oxford, a tried investigator, to study the origin of the excretory organs and other points in the development of the Crustacea, and more particularly the fertilisation process in the Decapods, and also to enable Mr. W. Wallace, B.Sc., Barry Scholar of the University of St. Andrews, to study viviparous fishes.

APPENDIX I.

Report on the Occupation of the Table of the British Association in the Zoological Station at Naples during the months of February, March, April, and May, 1901.

The Statocysts of Cephalopoda. By R. HAMLYN-HARRIS, *F.R.M.S., F.Z.S.*

Thanks to the kindness of the Committee of the British Association for the Advancement of Science, I was permitted to occupy their table from February 22 until June 3.

A great part of this time was occupied in the examination and study of the fauna of the Gulf of Naples.

My special object, however, in visiting Naples was to institute a thorough research into the organs for the maintenance of equilibrium (Gleichgewichtsorgane) in the Cephalopoda.

Of the Cephalopod species occurring in the Gulf of Naples the following were placed at my disposal and made use of by myself :—

Fam.—OMMASTREPHIDÆ.
Todaropsis Veranyi

Fam.—ONCHII.
Veranya sicula

Fam.—SEPIOLINI.
Sepiola rondiletii
Rossia macrosoma

Fam.—SEPIARII.
Sepia officinalis
Sepia Orbignyana
Sepia elegans

Fam.—LOLIGENII.
Loligo vulgaris
Loligo marmoræ

Fam.—ARGONAUTIDÆ.
Ocythoë tuberculata

Fam.—OCTOPIDÆ.
Octopus vulgaris
Octopus macropus
Octopus difilipii
Eledone moschata
Eledone Aldronanti

Young specimens as well as embryos of certain of the above species were also fixed and preserved.

Two of them, viz., Ocythoë tuberculata and Veranya sicula, are pelagic and comparatively rare. I was therefore able only to obtain a few specimens of these.

The only existing work on the so-called auditory organ of the Cephalopoda is that of Owsjannikow and Kowalevsky, published in 1867 in 'Memoires de l'Académie impériale des Sciences de St-Pétersbourg,' 7° série, tom. xi., No. 3.

This valuable memoir, containing as it does the result of extensive microscopical research, is, however, thirty-three years old, and science and microscopical methods have during that period made wonderful strides. It will therefore be readily seen that after so many years a more detailed histological examination of the same subject should yield important results.

In the majority of cases it was my practice to make use only of such parts of the head as I needed, and it was interesting to note that in every instance, among the Decapoda, at least, the statoliths were visible through the cartilage in specimens just killed, but that the transparency, as would be expected, disappears after fixing.

The cartilage of the Octopidæ seems to be less transparent, as it was only with difficulty that I could discern the statolith without opening the cyst.

The statolith, which dissolves in acetic acid, giving off a gas, when tested according to a well-known method proves to consist of carbonate of lime, and by this treatment a membrane enveloping the whole of the calcareous concrement is all that is left.

The statocysts of the Cephalopoda show the highest state of organisation among the invertebrata, occurring for the first time as stationary calcareous organs, held in place by an outer membrane, and situated on the Macula acustica.

The endolymph contained in the vesicle consists of a clear alkaline fluid, which is shown by the xanthoproteic reaction to contain albumen.

Time must necessarily elapse before my studies in this direction are completed, when I hope to publish the result of my labours.

I am continuing my studies at the Zoological Institute of Tübingen University.

I should like to take this opportunity to express my warm appreciation of the way in which the Zoological Station is managed, and my sincere thanks to the various members of the staff, especially Professor Eisig, Professor Paul Mayer, and Dr. Lo Bianco, for the many courtesies which they showed me, and the valuable advice and assistance which they were ever ready to give.

To the Committee of the British Association for the use of their table my especial thanks are due.

b. Report on the Occupation of a Table at the Stazione Zoologica, Naples, during March and April 1901.

The Fertilisation Process in Echinoidea.
By A. H. REGINALD BULLER, *B.Sc., Ph.D.*

I occupied the table of the British Association from March 20 until April 25.

The research work undertaken was a completion of a study of the causes leading to the union of the eggs and spermatozoa of the *Echinoidea.*

Further observations and experiments were made, supporting the conclusion, already reported, that chemotaxis plays no role in bringing the sex-cells into contact, and that the spermatozoa are probably incapable of responding to chemotactic stimuli.

Special attention was paid to the movement of the spermatozoa upon surfaces, and to the manner in which they penetrate the thick zona pellucida surrounding the eggs.

The following rule was found to hold good :—Whenever the spermatozoa come in contact with a surface bounding the medium in which they are moving, they cling to it, and they either become fixed to it almost at once or, more usually, rotate upon it. In the latter case, if the

surface be regarded from the point of view of the spermatozoa, the rotation, with rare individual exceptions, is always in the counter-clockwise direction.

The rotation phenomenon may be well seen when a drop containing not too many spermatozoa is placed upon an object-glass and examined under the microscope with a magnification of about 300 diameters. If the upper surface of the drop bounded by air be then carefully focussed, the spermatozoa clinging to it appear to the observer to revolve in the clockwise direction, but when the lower surface bounded by the glass is examined they are seen to move in a counter-clockwise direction.

The rotation rule was verified for five species of *Echinoidea*, and for representatives of all the other classes of *Echinodermata*. The species examined were the following :—

ECHINODERMATA.

Class 1.—HOLOTHUROIDEA.
Holothuria Stellati, D. Ch.

Class 2.—ECHINOIDEA.
Echinus microtuberculatus, Blv.
Sphærechinus granularis, Ag.
Arbacia pustulosa, Gray.
Strongocentrotus lividus, Brdt.

Class 3.—ASTEROIDEA.
Asterias glacialis, O. F. M.
Echinaster sepositus, Müll. Tr.

Class 4.—OPHIUROIDEA.
Ophioderma longicauda, Müll. Tr.
Ophioglypha lacertosa, Lyman.

Class 5.—CRINOIDEA.
Antedon rosacea, Norman.

It is a somewhat remarkable fact that rotation upon surfaces in a counter-clockwise direction was also observed by Dewitz [1] for the spermatozoa of certain insects. He believed that the spermatozoa were thus specially adapted for the purpose of finding their way into the micropyles of the eggs. Such an explanation could not, however, apply in the case of the *Echinodermata*, for no micropyles are present, and the gelatinous zona pellucida is everywhere penetrable.

The spermatozoa of the *Echinoidea* easily become attached to glass and other surfaces by the points of their conical heads upon which they often continue to revolve.

After becoming attached to the zona pellucida the spermatozoa make their way through it in a more or less radial direction. The penetration from the outer to the inner surface of the zona pellucida does not depend upon a chemotactic stimulus, for it was found that the phenomenon was equally well seen upon (1) ripe eggs, (2) eggs of full size which had not undergone maturation, and (3) eggs which had been killed with osmic acid and then washed. Penetration of the spermatozoa into the gelatinising outer wall of the oosporangium of *Cystocyra barbata* (one of the *Fucaceæ*) took place in a striking manner, the jelly becoming densely crowded. The spermatozoa likewise collected in great numbers in the jelly from the cell-walls of seeds of *Linum usatissimum*, and also in the zona pellucida of *Echinus* eggs after long separation by shaking.

The entrance of the spermatozoa into gelatinous substances, and also their attachment by the head to living eggs, is connected with their power of clinging and becoming attached to surfaces in general. The more or

[1] Dewitz, *Pflüger's Archiv*, Bd. 38, 1886, p. 358.

less radial penetration of the zona pellucida is possibly due to *stereotaxis*, but a purely mechanical explanation is not excluded.

Several writers, for instance Wilson,[1] and especially Verworn,[2] have supposed that chemotaxis is a constant factor in the fertilisation of animal eggs. This generalisation, which has been made by arguing from the attraction of spermatozoa to the eggs of certain plants, is as yet entirely without experimental justification as regards animals. From my own results, which agree with those obtained by Massart[3] in the case of the frog, and with the work of Dewitz[4] upon certain insects, I have been led to suppose that whereas contact phenomena are of great importance, chemotaxis, at any rate for a great number of animal species, plays no rôle whatever in bringing the spermatozoa and eggs into contact.

Before the close of the year I hope to publish a full account of my work.

It gives me much pleasure to acknowledge my indebtedness to the Committee of the British Association for the use of the table, and also to the staff at the Stazione Zoologica for their kindness and courtesy.

APPENDIX II.

A List of Naturalists who have worked at the Zoological Station from the end of June 1900 *to the end of June* 1901.

Number on List	Naturalist's Name	State or University whose Table was made use of	Duration of Occupancy: Arrival	Duration of Occupancy: Departure
1183	Dr. F. Bottazzi	Italy	July 1, 1900	Oct. 7, 1900
1184	Dr. F. Capobianco	,,	,, 1, ,,	Dec. 31, ,,
1185	Prof. A. Russo	,,	,, 3, ,,	Dec. 25, ,,
1186	Dr. V. Ariola	,,	,, 16, ,,	Sept.30, ,,
1187	Prof. F. Raffaele	,,	,, 17, ,,	Nov. 1, ,,
1188	Dr. E. Radl	Austria	,, 17, ,,	Aug. 13, ,,
1189	Dr. E. André	Switzerland	,, 18, ,,	Sept. 2, ,,
1190	Dr. D. Pedaschenko	Russia	,, 20, ,,	Aug. 20, ,,
1191	Dr. P. Enriquez	Italy	,, 25, ,,	Dec. 1, ,,
1192	Miss M. Pasquale	,,	Aug. 1, ,,	,, 31, ,,
1193	Dr. G. Mazzarelli	,,	,, 2, ,,	Sept.29, ,,
1194	Dr. E. Germano	Zoolog. Station	,, 4, ,,	Mar. 1, 1901
1195	Dr. A. Leontowitsch	Russia	,, 6, ,,	Aug. 31, ,,
1196	Dr. F Mazza	Italy	,, 11, ,,	Sept.15, ,,
1197	Dr. T. Meisenheimer	Prussia	,, 15, ,,	Sept.24, 1900
1198	Dr. E. Crisafulli	Italy	,, 15, ,,	—
1199	Prof. S. Apáthy	Hungary	,, 18, ,,	,, 28, 1900
1200	Prof. F. S. Monticelli	Italy	,, 20, ,,	—
1201	Prof. G. Czokor	Austria	,, 26, ,,	Oct. 15, 1900
1202	Prof. F. Sanfelice	Italy	,, 28, ,,	Nov. 13, ,,
1203	Prof. P. Francotte	Belgium	,, 30, ,,	Oct. 13, ,,
1204	Prof. A. Richter	Hungary	,, 31, ,,	Sept.11, ,,
1205	Prof. H. Bachmann	Switzerland	,, 31, ,,	Oct. 26, ,,
1206	Dr. W. Straub	Saxony	Sept. 6, ,,	Nov. 4, ,,

1, 4 E. B. Wilson, *The Cell in Development and Inheritance*, 2nd edition, 1900, p. 196.

2 Verworn, *Physiologie*, 1895, p. 425.

3 Massart, *Bulletins de l'Acad. roy. des Sci. de Belgique*, 3e sér., tom. xv., No. 5, 1888, and tom. xviii., No. 8, 1889.

4 *Loc. cit.*

A LIST OF NATURALISTS *continued.*

Number on List	Naturalist's Name	State or University whose Table was made use of	Duration of Occupancy Arrival	Departure
1207	Dr. F. Marino .	Italy . . .	Sept. 8, 1900	Oct. 19, 1900
1208	Prof. C. Mensch	Smithsonian Table .	„ 11, „	Sept. 22, „
1209	Dr. M. Henze .	Zoolog. Station	Oct. 1, „	—
1210	Prof. W. T. Porter	University Table .	„ 6, „	Nov. 17, 1900
1211	Mr. L. Doncaster	Cambridge . .	„ 7, „	June 30, 1901
1212	Dr. O. Cohnheim	Baden . . .	Nov. 21, „	Apr. 24, „
1213	Dr. G. Cecconi .	Italy . . .	„ 26, „	Feb. 5, „
1214	Dr. G. Mann	Oxford . . .	Dec. 15, „	Jan. 10, „
1215	Baron T. v. Uexküll .	Hesse . . .	„ 17, „	—
1216	Dr. N. Goronowich	Zoolog. Station	„ 22, „	Dec. 31, 1900
1217	Dr. A. Nathansohn	Saxony . . .	Jan. 1, 1901	—
1218	Dr. von Dungern	Prussia . . .	„ 1, „	Apr. 18, 1901
1219	Dr. G. Jatta .	Zoolog. Station	„ 1, „	—
1220	Dr. G. Tagliani	Italy . . .	„ 1, „	—
1221	Dr. V. Diamare.	„ . . .	„ 1, „	—
1222	Dr. F. Capobianco	„ . . .	„ 1, „	—
1223	Dr. M. Pierantoni	„ . . .	„ 1, „	—
1224	Prof. T. d'Evant	„ . . .	„ 1, „	
1225	Dr. G. Rossi .	„ . . .	„ 1, „	—
1226	Prof. C. Gioffredi	„ . . .	„ 1, „	—
1227	Miss Buchanan.	Oxford . . .	„ 21, „	Feb. 9, 1901
1228	Dr. E. Bresslau .	Strassburg . .	Feb. 5, „	Apr 4, „
1229	Dr. M. Philippson	Belgium . . .	„ 10, „	„ 26, „
1230	Miss C. Clapp .	American Women's Table	„ 11, „	May 23, „
1231	Miss L. Wallace	„ „ .	„ 11, „	„ 23, „
1232	Dr. E. Riggenbach	Switzerland . .	„ 13, „	Apr. 13, „
1233	Dr. H. Harris .	*British Association* .	„ 21, „	June 2, „
1234	Dr. H. Winkler.	Würtemberg . .	Mar. 4, „	Apr. 16, „
1235	Dr. H. Miehe .	Prussia . . .	„ 6, „	„ 27, „
1236	Dr. A. Fischel .	Austria . . .	„ 9, „	„ 16, „
1237	Dr. P. Röthig .	Prussia . . .	„ 9, „	Mar. 15, „
1238	Dr. O. Maas .	Bavaria . . .	„ 11, „	May 25, „
1239	Dr. C. Günther.	Baden . . .	„ 12, „	Apr. 18, „
1240	Prof. G. Karsten	Prussia . . .	„ 14, „	„ 20, „
1241	Dr. A. Buller .	*British Association* .	„ 18, „	„ 22, „
1242	Stud. C. Thesing	Hamburg . .	„ 20, „	June 12, „
1243	Dr. M. Tobler .	Switzerland . .	„ 20, „	„ 12, „
1244	Miss C. Bonnevie	Zoolog. Station .	„ 25, „	Apr. 16, „
1245	Prof. S. Exner .	Austria . . .	„ 29, „	„ 24, „
1246	Dr. F. Kopsch .	Prussia . . .	„ 30, „	„ 29, „
1247	Dr. F. Stevens .	Smithsonian Table .	Apr. 2, „	„ 26, „
1248	Dr. G. Mazzaretti	Italy . . .	„ 2, „	„ 16, „
1249	Prof. L. Fredericq	Belgium . . .	„ 6, „	June 1, „
1250	Dr. R. Burton Opitz.	University Table .	„ 27, „	—
1251	Prof. D. Carazzi	Italy . . .	„ 27, „	—
1252	Prof. T. Vosseler	Würtemberg . .	May 2, „	June 4, 1901
1253	Dr. H. Kluge .	Russia . . .	June 3, „	—
1254	Miss Fl. Peebles	American Women's Table	„ 28, „	—

APPENDIX III.

A List of Papers which were published in the year 1900 by the Naturalists who have occupied Tables in the Zoological Station.

D. Carazzi . . .	L'Embriologia dell' Aplysia limacina L. Anatomischer Anzeiger, 17 Bd. 1900.
" . . .	Ricerche sul Plankton del lago Fusaro in rapporto con la Ostricoltura. Boll. not. agr. Minist. Agric. Anno 22, 1900.
H. Herbst . . .	Über das Auseinandergehen von Furchungs- und Gewebezellen in kalkfreiem Medium. Archiv f. Entw. Mech. Roux 9 Bd. 1900.
H. M. Vernon . .	Cross-fertilisation among Echinoids. Archiv f. Entw. Mech. Roux 9 Bd. 1900.
" . .	Certain Laws of Variation. I. The Reaction of Developing Organisms to Environment. Proc. Royal Society, vol. 67, 1900.
A. Romano . . .	Intorno alla natura ed alle ragioni del colorito giallo dei centri nervosi elettrici. Anatomischer Anzeiger, 17 Bd. 1900.
S. Garten . . .	Die Veränderungen in den Ganglienzellen des elektrischen Lappens der Zitterrochen nach Durchschneidung der aus ihm entspringenden Nerven. Archiv f. Anat. u. Physiol. Anat. Abth. 1900.
R. C. Punnett . .	On the formation of the Pelvic Plexus, with special reference to the nervus collector in the genus Mustelus. Phil. Trans. Royal Society, London, vol. 192, 1900.
H. Winkler . . .	Über die Furchung unbefruchteter Eier unter der Einwirkung von Extrativstoffen aus dem Sperma. Nachr. k. Ges. Wiss. Göttingen, 1900.
B. Schröder . . .	Das Phytoplankton des Golfes von Neapel, nebst vergleichenden Ausblicken auf das des atlantischen Oceans. Mitth. Z. Station, vol. 14, 1900.
V. Faussek . . .	Untersuchungen über die Entwickelung der Cephalopoden Mitth. Z. Station, vol. 14, 1900.
G. Duncker . . .	Biologische Beobachtungen an Lophobranchiern. Abh. aus d. Geb. der Naturw. Verein Hamburg, 16 Bd. 1900.
W. Lindemann . .	Über die Wirkung des Phosphors und des Pulegons auf die Cephalopoden. Beiträge path. Anat. u. Pathol. Ziegler, 27 Bd. 1900.
" . .	Urämie bei Cephalopoden. *Ibid.* 1900.
A. Russo . . .	Sull' aggruppamento dei primi elementi sessuali nelle larve di Antedon rosacea. Rend. Accad. Lincei, vol. 9, 1900.
" . . .	Sulla funzione renale dell' organo genitale delle Oloturie (sunto). Rendic. 1 Assemblea Unione Zoologica Ital. Bologna, 1900.
E. Germano . . .	La Tuberculosi sperimentale nei Pesci. Arte medica, Anno II. 1900.
F. Bottazzi and P. Enriquez	Sulle proprietà osmotiche delle glandole salivari posteriori dell' Octopus macropus. Milano, 1900.
H. Przibram . . .	Experimentelle Studien über Regeneration. Biolog. Centralblatt, 20 Bd. 1900.
C. K. Schneider . .	Mittheilungen über Siphonophoren Nesselzellen. Arb. Z. Inst. Wien, 12 Bd. 1900.
Rina Monti . . .	La Rigenerazione nelle Planarie marine. Memorie Istituto Lombardo Scienze e Lettere, vol. 19, III. 1900.
E. S. Goodrich . .	On the Nephridia of the Polychæta. Part III. Quart. Journ. Micr. Sc., vol. 43, 1900.
" . .	Observations on Syllis vivipara Krohn. Journal Linnean Society, vol. 28, 1900.

O. Carlgren . .	Über die Einwirkung des constanten galvanischen Stromes auf niedere Organismen. Archiv f. Anat. und Phys., Phys. Abth., 1900.
" . . .	Zur Kenntniss der stichodactylinen Actinarien. Öfv. Kong. Vetensk. Akad. Förh., 1900.
D. M. Mottier. . .	Nuclear and Cell Division in Dictyota dichotoma. Annals of Botany, vol. 14, 1900.
T. H. Morgan and P. A. Hazen.	The Gastrulation of Amphioxus (*partim*). Journal of Morphology, vol. 16, 1900.
Florence Peebles . .	Experiments in regeneration and in grafting of Hydrozoa. Archiv f. Entw. Mechanik Roux, 10 Bd. 1900 (*partim*).
H. Jordan . . .	Über die Anwendung v. Celloïdin in Mischung mit Cedernholzöl. Zeitschr. f wiss. Mikros. 17 Bd. 1900.
F. B. Sumner . . .	Kupfer's Vesicle and its Relation to Gastrulation and Concrescence (*partim*). Mem. N. Y. Acad. of Sc., vol. 2, 1900.
F. Raffaele . . .	Per la Genesi dei Nervi da Catene cellulari (*partim*). Anat. Anzeiger, 18 Bd. 1900.
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F. S. Monticelli and S. Lo Bianco	Sullo sviluppo dei Peneidi del Golfo di Napoli (note riassuntive). Rendic. 1 Assemblea Unione Zool. Ital. Bologna, 1900.
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A. Borgert . . .	Untersuchungen über die Fortpflanzung der tripyleen Radiolarien, speciell von Aulacantha scolymantha. Zool. Jahrb. Abth. Anat. und Ontog. 14 Bd. 1900.

APPENDIX IV.

A List of the Publications of the Zoological Station during the year ending June 30, 1901.

1. 'Fauna und Flora des Golfes von Neapel.' P. Falkenberg, Rhodomelaceen, 776 pp., with 24 plates
2. 'Mittheilungen aus der zoologischen Station zu Neapel.' Vol. xiv. parts 3 and 4, with 8 plates.
3. 'Zoologischer Jahresbericht' for 1899.
4. 'Guide to the Aquarium.' A new English edition is being prepared.

Index Animalium.—*Report of the Committee, consisting of* Dr. HENRY WOODWARD (*Chairman*), Mr. W. E. HOYLE, Mr. R. MCLACHLAN, Dr. P. L. SCLATER, Rev. T. R. R. STEBBING, *and* Dr. F. A. BATHER (*Secretary*).

THE Committee has the honour to report that during the last year the whole of the entries covering the period from 1758-1800 have been arranged, sorted, the duplicate entries eliminated, and the remainder—about 62,000—got ready for press. Of these perhaps some 6,000 are duplicates, but owing to the loose methods of authors the compiler cannot decide, and it has been thought better to include them, leaving it to the specialist to reject such duplicates rather than to run the risk of omitting a possibly important entry. Negotiations entered into with the Cambridge University Press have ended in a satisfactory manner, and the work of printing this first part of the Index was begun at the end of May 1901. The work will take about twenty months to go through the press, will comprise some 1,000 pages, and will be provided with an index to the trivial names under genera, the same slips as are used for the main work being re-sorted under genera as fast as they come off the press. This method has been adopted for several reasons, *e.g.*, the great expenditure of time if a copy of all the slips were made, and the fact that those who desire to know what trivial names are included under a genus can as easily refer to the end as to the body of the book.

A complete list of works consulted has been prepared, and will be printed: this will be annotated throughout with bibliographic notes as to dates and contents, and should prove of considerable value to librarians and others as regards the rarer literature. It is gratifying to be able to report that very few publications have eluded the search of the compiler, but these Mr. C. Davies Sherborn does not regard as likely to be of importance. They may possibly contain a few specific names, but it is hardly probable.

The indexing of 1801-1900 continues, and will proceed more rapidly now the early MS. is out of hand. It is hoped that the finished work, when it appears, will fully justify both the time spent upon it and the generous support received from the British Association, the Royal Society, and the Zoological Society, and that the Committee will have placed at its disposal an even more liberal support in the future. It must be remembered that up to the present every entry, and every portion of the purely mechanical part of the work, has been done by Mr. Sherborn, and that many months of his time could have been saved for the more important labour of recording had the Committee been able to pay for the assistance of even a boy to do the sorting, alphabetical arrangement, and numbering of the slips. However, as it is, we have now the results of the labours of one man, and the Committee regards this as showing in a most satisfactory manner the definite plan of the proposer and compiler of this colossal undertaking.

The Committee earnestly requests its reappointment, with a grant of 100*l.*

Coral Reefs of the Indian Regions.—Second Report of the Committee, consisting of Mr. A. SEDGWICK (*Chairman*), Mr. J. GRAHAM KERR (*Secretary*), Professor J. W. JUDD, Mr. J. J. LISTER, *and* Dr. S. F. HARMER, *appointed to investigate the Structure, Formation, and Growth of the Coral Reefs of the Indian Region.*

THE Committee have received the following report from Mr. J. Stanley Gardiner :—

During the greater part of the year I have been engaged single-handed in sorting and properly labelling the marine collections from the Laccadive and Maldive Archipelagoes. This is now completed, and they are divided into groups, each with our notes as to localities, depths, &c.

For more than thirty of the groups I have been promised the services of various zoologists in this country. About half of these have already received their collections, and I hope to forward the remainder shortly. I have, up to the present, received reports from Mr. P. Cameron (Hymenoptera, 25 species, 16 new), Mr. R. C. Punnett (Nemerteans, 12 species, 9 new), Mr. Ed. Meyrick (Lepidoptera, 66 species, 4 new), Mr. F. F. Laidlaw (Reptilia), and Mr. Oldfield Thomas (Mammalia). In addition, Mr. Borradaile has sent me a complete memoir on the Land Crustaceans, and I have prepared a great part of my report on the structure, formation, and growth of the reefs. The land flora of the group has now been worked out, and a complete report on it will shortly be published by Mr. J. C. Willis and myself in the 'Journal' of the Pere-deniya Gardens, Ceylon.

The collections so far seem to justify the conclusions, drawn in my last report, as to their completeness. Dr. David Sharp, who has taken charge of the insect collections, has expressed considerable satisfaction both as to their exhaustiveness and state of preservation, and Professor Hickson writes as follows : 'There is quite enough to show the general character of the shallow water fauna (Alcyonaria, 0–50 fathoms), and it is not probable that many new species will be found in this region after the collection has been worked out.'

Publication, in view of the large number of new species, is an extremely difficult matter, especially as it seems very desirable that the reports should be kept together. I may draw attention to the general opinion expressed at the International Congress of Zoology (1898) as to the desirability of properly illustrating new species wherever possible. The University Press (Cambridge) have undertaken the publication in a series of eight quarto parts, each of about 120 pages, on the condition that they are not called upon to expend more than 200*l.* on illustrating the work. It is calculated that at least seventy plates and 150 text-figures would be required to adequately illustrate the fauna and geography. These cannot be prepared in a suitable manner for less than 450*l.*, and I would ask your assistance towards the additional 250*l.* required.

The Committee seek reappointment.

Bird Migration in Great Britain and Ireland.—Fourth Interim Report of the Committee, consisting of Professor NEWTON (*Chairman*), Rev. E. P. KNUBLEY (*Secretary*), Mr. JOHN A. HARVIE-BROWN, Mr. R. M. BARRINGTON, *and* Mr. A. H. EVANS, *appointed to work out the details of the Observations of Migration of Birds at Lighthouses and Lightships*, 1880–87.

YOUR Committee has again great pleasure in reporting that Mr. William Eagle Clarke has been continuing his invaluable services, and the subjoined statement received from him, together with a Summary of Observations in reference to the Migrations of the Skylark (*Alauda arvensis*) and the Swallow (*Hirundo rustica*)—the former being of an extremely complicated nature—shows the results of an enormous amount of labour, wrought out with proportionate skill, of which your Committee desires to express its most grateful admiration.

A serious deficiency of data in regard to the migrations of some other species on the south coast of England has become apparent, and, at the suggestion of Mr. Clarke, application was made to the authorities of the Trinity House to permit a renewal of observations at the Lighthouses and Lightships along that coast. The consent of the Elder Brethren having been most courteously given, and the cost defrayed from private sources, the necessary schedules have been forwarded to the several stations. Your Committee is aware that in thus acting it may have exceeded its duties according to the strict terms of its appointment, but trusts that, in the circumstances, the transgression (if it be so regarded) will be pardoned, seeing that its object was to supply a void left through inadvertence by the older Migration of Birds Committee; that it introduced no new principle; and, moreover, that otherwise a whole year would have been lost.

On two previous occasions your Committee has referred to the private labours of one of its members (Mr. Barrington) in regard to observations at the Irish Lights. These have now been published *in extenso*, forming a volume[1] which is perhaps the most monumental contribution to the literature of Bird Migration ever issued; while its appendix, giving the precise wing-measurements of so many specimens, is, apart from the subject it especially illustrates, a matter of importance for the student of variation. Thanks, too, to that gentleman's exertions, the work has the additional merit of containing the results of ten years more than the period covered by the inquiry carried on by the Association's former Committee; a fact which enormously enhances the value of the Irish records.

Without pledging itself to a positive assurance in the matter, your Committee hopes that, if reappointed, as it desires to be, it will, in the course of two years more, bring to a conclusion the work with which it has been charged, so far as being able to give a summary of the movements

[1] The Migration of Birds as observed at Irish Lighthouses and Lightships, including the original Reports from 1888–97, now published for the first time, and an analysis of them and of the previously published Reports from 1881–87, together with an appendix giving the measurements of about 1,600 wings. By Richard M. Barrington, M.A., LL.B., F.L.S. London and Dublin: [1890] (pp. xxvi + 285 + 667).

of the most representative species of migrants. The Song-Thrush, White Wagtail, Skylark, and Swallow being now done, it is proposed to invite Mr. Clarke's attention to a like treatment of the Starling, Rook, Lapwing, and some others, which will presumably present no little divergence in the character of their migrations.

Thus your Committee respectfully repeats its request for reappointment, and, if possible, with an increased grant of money.

Statement made to the Committee.
By WM. EAGLE CLARKE.

During the past year I have devoted much time to the study of the seasonal movements of a number of our birds, and I present herewith, for the consideration of the Committee, histories of the various migrations performed annually within the British area by the Skylark and the Swallow.

The preparation of these complete and particular accounts has proved to be a laborious and difficult undertaking, since a number of the movements to be treated of are so intricately interwoven with or so insensibly merge into each other, or are performed under such obscure conditions, as to render their discrimination and interpretation matters demanding most careful consideration.

The following accounts of the migrations of the Skylark and the Swallow are in the main based upon the data obtained at the Light-stations and elsewhere during the years 1880–87; but other sources of information have been consulted, including the Scottish Migration Reports for 1892–1900 of Messrs. Hinxman and Laidlaw, and the Irish Reports for 1888–97 of Mr. Barrington.

It is my pleasing duty to acknowledge the assistance I have received from Professor Collett, of Christiania, who has most obligingly furnished me with useful notes relating to the movements of birds in Southern Norway; and from Herr Knud Andersen, of Copenhagen, who has given me much valuable information on the migratory birds observed in the Færoe Islands.

THE MIGRATIONS OF THE SKYLARK (*Alauda arvensis*).

In the British Islands the Skylark is not only one of the best-known species, but also one which can be almost always met with, so that comparatively few people suspect the extent to which it is migratory, and fewer still are aware of the complexity of its migrations, which present problems more difficult to solve than those of any other British bird; yet this is undoubtedly the case.

As a migrant, no species makes so great a show in the returns of the several Light-stations, and the account which follows is based upon upwards of *four thousand* individual records. Yet within the British area the Skylark is for the most part Resident as a species, though shifting its quarters when affected by frost or snow, as is obvious to almost any observer. The degree to which our native Skylarks are migratory depends on the varying conditions of climate and food. In the lowlands of Great Britain, especially in the south-west of England and throughout Ireland generally, the migratory habit is less exercised, presumably because it is less necessary there than elsewhere. On the other hand there are considerable tracts which, from their elevated, exposed, or

northerly situation, are not suited for winter residence, and to those the Skylark is merely a Summer Visitor, as it is to nearly the whole of Northern and a great part of Central Europe, departing after the breeding season to its accustomed winter quarters. During its journeyings to the south and west in the fall of the year, and again on its return in spring, the Skylark appears in vast numbers on our coasts as a Bird of Passage, while, owing to their intermediate geographical position and their milder climate, the British Islands are much resorted to by the Continental Skylark as a Winter Visitant.[1]

The various migrations of the species may be conveniently separated and arranged as follows, beginning with the autumnal movements; and when it is considered that several of these movements are often simultaneously in progress, some idea of their complexity and the extreme difficulty of their interpretation may be realised:—

1. Autumn Emigration of Summer Visitants, with their offspring, *i.e.*, home-breeding and home-bred birds.
2. Autumn Immigration of Winter Visitants from Central Europe.
3. Autumn Immigration of Winter Visitants from Northern Europe.
4. Autumn Passage from Central to Southern Europe along the British coast.
5. Autumn Passage from Northern to Southern Europe along the British coast.
6. Winter Emigration from, and Partial Migration within, the British Islands.
7. Spring Immigration of Summer Visitants, and return of Winter Emigrants.
8. Spring Emigration to Central Europe from the British Isles.
9. Spring Emigration to Northern Europe from the British Isles.
10. Spring Passage from Southern to Central and Northern Europe along the British coast.

But even this is not all, for the movements which take place between Great Britain and Ireland, as well as between Great Britain and the Hebrides and Northern Islands, have also to be considered.

1. *Autumn Emigration of Home-bred Birds.*—Towards the close of the nesting season an increased number of Skylarks is observable in the lowlands, particularly near the coast; a fact due, no doubt, to migration from the higher grounds, to which the species is only a summer visitor. So early as July in some years there are a few records from the Light-stations showing that departure has already commenced, but these early flittings must be regarded as exceptional.[2] During August there are usually a few signs of emigration, and towards the end of that month there is evidence that it has fully set in. These late August movements

[1] No unfailing distinction between British and foreign Skylarks has hitherto been recognised by ornithologists generally. In attempting to draw one here, the writer has chiefly relied upon what can, with more or less probability, be presumed as to the origin of the particular flocks from connecting the different observations of them whereby their course may be traced.

[2] The most remarkable instance of this kind occurred on the night of July 25, 1881, when a great number of Skylarks appeared at the Leman and Ower Lightship, off the Norfolk coast, and *sixty* were killed by striking the lantern, and at the same time *fifty* were killed at the Dudgeon, a neighbouring Lightship. The weather was wet, changeable, and cold for the time of year.

include departures from the Hebrides and other western isles, as witnessed by birds observed at or killed against the lanterns of Skerryvore and Dhuheartach, but there is no appearance of any emigration from Ireland in this month, which is a rather remarkable and significant fact. Throughout September the emigration is much more evident on both eastern and western coasts, the Hebrides contributing largely to the latter. In some seasons a marked migration is recorded from Shetland,[1] where the species is chiefly a summer visitant. In Ireland, too, there is evidence from the south-eastern stations that the exodus has begun. Towards the end of the month the movement is more marked, especially in unsettled weather, when Skylarks are recorded as emigrating by night in company with Thrushes, Blackbirds, Ring-ousels, Wheatears, Chiffchaffs, Whitethroats, Wagtails, and other birds. As the season advances emigration is naturally quickened until the early days of November, when this movement ceases to be observed. In some years a foretaste of winter, in others periods of exceptionally unsettled weather cause pronounced 'rushes' southward.[2]

During the autumn Skylarks gradually draw towards the coast, on reaching which they pass southwards in straggling parties. On some days a succession of bands may be seen following each other throughout the whole day, and in September and October, if the weather be fine with light winds, such bands may be observed for days together without a break. This coasting movement is chiefly, if not entirely, performed by day; but it is otherwise when a considerable expanse of sea is to be crossed, as from Shetland, the Hebrides, or Ireland, and then their migration as a rule is undertaken by night. The journey is continued along both coasts of Great Britain until the southern and particularly the south-western counties are reached, many of the east-coast migrants passing along the south coast westward. Probably, only a portion of the Skylarks, which move during the early autumn, quit our shores, many no doubt tarrying on the south or south-western coast. Others, however, certainly depart for the Continent, crossing the Channel chiefly at night together with birds of many other species; but I myself in passing between Newhaven and Dieppe in September have observed small parties of Skylarks in mid-channel making for the French coast during the daytime.

2. *Autumn Immigration from Central Europe.*[3]—This movement is the most interesting and remarkable performance of the Skylark, or perhaps of any other British species, as it affords a striking instance of the phenomenon of birds proceeding westward, and possibly northward, from their breeding grounds to reach their winter quarters, and this in vast numbers for several successive weeks, with scarcely a break. In some seasons this Immigration—which may be called especially the Skylarks' route, since they not only greatly outnumber the birds of any other

[1] The date of the first movement from Shetland varies according to the nature of the season. In 1882 it was observed as early as September 15, and in 1886 on September 25. The autumn emigration thence does not usually begin until October.

[2] There can be little doubt that during October and November the emigration of our home-bred Skylarks merges to some extent with the Passage movement from Northern to Southern Europe then in progress along our coasts.

[3] Evidence accumulated since the presentation of the 'Digest of Observations' (*Rep. Brit. Assoc.*, 1896, p. 456) confirms the reasons therein stated for considering Western Central Europe one of the areas whence Skylarks and certain other birds emigrate to the British Islands.

species using it, but probably the whole aggregate—sets in as early as the middle of September, but more commonly about the fourth week of that month. On reaching our coast the majority of the immigrants move along it southward, and then westerly to the Land's End, some crossing the Channel at various points to the French coast, while others seem to continue westward or northward to Ireland, appearing on the coast of Wexford at dates varying from the middle to the end of the month, but having relation to those of their arrival on the east coast of England. A considerable number of the Immigrants, however, on their arrival in England proceed inland, and disperse over the eastern, southern, and midland counties. It is in October, however, that this stream of immigration becomes phenomenal. It then has the coast of Suffolk for its centre, with its right wing extending to the Humber, or even to or beyond the Tees; while the left, to some extent reinforced by birds of British origin, sweeps along the south coast to Devon and Cornwall, and, as in September, to Ireland. The winter visitants among these October immigrants pass inland by several routes; a good many proceed up the Thames and Humber estuaries. Some idea of the magnitude of this influx may be gathered from this table, showing the number of days during October on which it was observed in each of the years:

1880. 22 days	1883. 9 days	1886. 23 days
1881. 12 „	1884 19 „	1887.[1] 26 „
1882. 14 „	1885 21 „	

After October this Immigration falls off. The November movements vary according to the weather, but are never of great moment after the first few days of the month, when in most years they practically cease. In November 1883 and 1886 no east-to-west movements were recorded.

It is characteristic of this immigration that the passage across the North Sea is invariably witnessed during the daytime, usually from dawn to noon, but not unfrequently prolonged till 3 P.M., and the birds concerned in it are actually crossing the line of flight taken by the home-bred birds which are then emigrating; a very remarkable but not very uncommon occurrence in October. Other species crossing the North Sea at this time in company with the Skylarks are Starlings, Titlarks, Chaffinches, Linnets, Blackbirds, and Rooks.

3. *Autumn Immigration from Northern Europe.*—Great numbers of Skylarks which summer in Scandinavia,[2] seek our shores in autumn, their first arrival during the years 1880–87 being remarkably constant (October 4 to 8), when the birds appear in Shetland, Orkney, on the east coast of Scotland and north-east coast of England, during the night or early in the morning, in company with Thrushes, Redwings, Blackbirds, Ring-ousels, Goldcrests, Chaffinches, Bramblings, and other species breeding in the north. These arrivals continue, at intervals, during October, and the Skylark participates largely in those remarkable movements which characterise the latter part of the month. These vast outpourings seem to exhaust the emigration from Northern Europe, for it was only during two years (1883 and 1884) of the inquiry that considerable arrivals from

[1] Many recorded on October 9, 20, 21, 23, and 27; vast numbers on October 16 to 18, again on 22, 25, and 26.

[2] Professor Collett says (*Oversigt af Christiania Omegns ornithologiske Fauna*, p. 128) that *Alauda arvensis* is seldom seen in the Christiania district after the middle of October.

the north are recorded for November, carrying the extreme limit of the period covered by this movement of the Skylark down to the 15th of that month. Thus the autumnal immigration from the north, vast as it is, is compressed, as it were, into the period of little more than four weeks. The majority of these northern skylarks seem to disperse themselves over our islands, some of them reaching the Hebrides, and replace the home-bred birds which have already quitted their summer haunts. A great many seek Ireland, either by direct passage from the south-west of Scotland or by way of the Isle of Man, while some may pass from the Welsh coast to the shores of Dublin and Wicklow.

4 and 5. *Autumn Passage from Central and Northern Europe to Southern Europe along the British Coast.*—These movements are much involved with the immigratory movements from the north and east, and, to a lesser degree, with the British emigratory movements already treated of. The transient visitors which effect it arrive on our northern islands and along our north-eastern coast, together with those which winter with us, in October, or in some years early in November, and after a short rest proceed along the coast, chiefly by night, southward and westward, crossing the Channel at various points. Though they are mainly confined to our eastern and southern seaboards, yet a considerable number make an overland journey across Great Britain, travelling down the west coast, while others possibly cross to Ireland, and continue their southerly journey along its eastern shores. The Passage movements from the east need no further notice now, since they have been treated already under Section 2.

General Remarks on Autumn Emigration and Immigration.—Having treated of the autumn movements, both of emigration and immigration, it may be desirable before proceeding further to consider their effects on the Skylark population of Britain, and its position at the end of that season. Though a considerable number of home-bred birds have at that time quitted our shores, their departure has not materially affected the great abundance of the species, partly owing to the fact that the Skylark is double-brooded,[1] and hence its annual increase is enormous, while prodigious numbers have poured into England from Central Europe during part of September and throughout October, to say nothing of the immense number of immigrants from North-western Europe which have arrived during the latter month. The result is that from November to the setting in of cold weather the Skylark population of the British Isles is at its maximum, and vastly in excess of what it is at any other period of the year.

6. *Winter Emigration from, and Partial Migration within, the British Islands.*—These movements depend wholly on the state of the weather, and vary in degree according to its severity. The Skylark obtaining the whole of its food on the ground is at once driven to change its quarters when that is covered with snow, and only somewhat less quickly when it is merely frost-bound without snow. Should the late autumn and winter be uniformly mild, the Skylarks sojourning with us remain practically stationary. Few, if any, winters are, however, entirely free from snow or frost, and with the first outbreak of cold the birds must remove themselves from its untoward influence. Sometimes suitable lodging may be found not far off, and then the movement is but local or partial in character. When this occurs, and the stress is but short, the birds soon

[1] In many parts of England most pairs of Skylarks have three nests in the year.

return to their former haunts; but if the adverse conditions continue and become general, the movement also becomes widespread and more or less universal. This effect is especially produced by great snowstorms, when the number of fugitives is so vast that people wonder where such prodigious multitudes can come from, as they throng towards the coast and particularly the milder south-west coast of England—Devon, Cornwall, and the Scilly Isles—though many undoubtedly cross the Channel, and others proceed to Ireland. On the other hand, a few—and these are, perhaps, of our native stock—attempt to brave the unfavourable conditions, partly by resorting to unwonted places of shelter, especially the sea-shore, but many, if not most, of them succumb to famine. In Ireland, too, there are many winter movements, due to the pressure of climatic conditions, and Cork and Kerry are especially resorted to during hard weather; but winter emigration must be regarded as exceptional in Ireland, for one portion or another of its shores generally affords an asylum in the severest seasons, though many birds perish, even in its most favourable areas, during an abnormally protracted winter. It has already been stated that Ireland ordinarily receives numbers of Skylarks in autumn, and being again sought by multitudes of refugees from the snows and frosts of Great Britain, it follows that the Skylark population of Ireland is at its maximum at a period when that of Great Britain is at its lowest.

During some severe winters in Central Europe there is a renewal of the immigration of Skylarks (together with Starlings and Lapwings) across the North Sea to the south-east coast.

During these cold-weather movements many of the emigrants perish at the lanterns of the Light-stations. Thus, on December 2, 1882, the Bell Rock Lighthouse was visited by what is described as being the greatest multitude of Skylarks ever known. It was impossible to estimate the number, but they were 'striking hard for a couple of hours like a shower of hail.'

If the statement that the winter emigration depends wholly on the state of the weather need any confirmation, it may be furnished by the fact that in the mild seasons of 1881–82 and 1885–86 very little was recorded. There are, however, usually spasmodic and partial movements in November; but it is not until cold weather sets in that any general exodus takes place. If there has been much snow in December, as in 1879 and 1882, there is little or no movement later in the season, because the birds have already departed. On the other hand, after the uneventful December of 1880, there were pronounced emigrations in January 1881. In February there are, as a rule, movements more or less local, and due to snow, and in that month of 1886, which was cold and snowy, movement followed movement throughout its course. The March migrations are not of much account, but in unusually inclement seasons, like 1883 and 1887, there were 'rushes' to the coast as late as the 20th of that month.[1] In other years there is little or nothing recorded for it.

7. *Spring Immigration of Summer Visitants and Return of Winter Emigrants.*—The return of the Skylarks which have left us during the autumn and winter is observed on the southern coasts of both Great Britain and Ireland early in the year, their arrival taking place as a rule

[1] At the Nash Lighthouse, on the Glamorgan coast, on March 15, 1887, Skylarks, Starlings, Snipes, Woodcocks, Lapwings, Golden Plovers, and Wild Ducks were seen flying before heavy snow from 8 30 A.M. to 3 P.M.

during the latter half of February, and occasionally as early as the second week (in 1886 on the 11th), the immigration continuing throughout March. The precise time seems to be influenced by the condition of the weather in the birds' southern retreats. If the early spring there be mild and genial, they begin their return early, but if the contrary their departure is delayed. On arrival on the south coast of England many pass northward along the east and west coasts, the latter being the route chiefly followed by the earlier immigrants. The return to Ireland corresponds closely with the arrival in Southern England, the earliest observation for the period 1882–87 being on February 10, 1886, and from that time the movements occur at intervals. The other species of birds which reappear along with the Skylarks are mostly those which have before been mentioned in association with them—Thrushes, Blackbirds, Titlarks, Lapwings, and so forth. During April the movements of the immigrants become merged into those of the strictly called Birds of Passage. In Ireland, during the first half of the month and occasionally to the third week, Skylarks continue to arrive in company with Wheatears and other early summer birds. The return movement to the Hebrides corresponds with that to the mainland, but, as in Ireland, the immigration is prolonged into April. In Shetland the spring arrival of the native birds begins in the early days of March. The immigrants reach the south coast of England, sometimes in vast numbers, during the earliest hours of the morning, but in the south-east of Ireland, the chief point of arrival in that country, they are usually observed later in the day, but in the Hebrides at night.

8. *Spring Emigration to Central Europe from the British Isles.*—The return (west to east) movement from South-eastern England across the North Sea comes very little under observation compared with the inflowing streams of the preceding autumn, and that this should be so is easily to be explained. In the first place, the numbers of travellers, owing to the waste of winter, have been much thinned; and secondly, because, like all other important emigratory movements, this one takes place chiefly at night, and so for the most part escapes notice, for it is reasonable to suppose that the first hour of flight takes the birds beyond the limit of observation at the Light-stations along our eastern coast. Some return emigration is nevertheless observed by day on the Lightships, the direction of the birds being eastward from the mouth of the Thames, and south-eastward from the more northerly stations. There are also enough observations to show that the movement begins in February (in the mild season of 1882 on the 6th, but usually not till the middle of the month), and is continued until the end of March, the 28th being the latest day recorded. As with the reverse movement in autumn, this is chiefly noticed on the Lightships between the Thames and the Humber. The other species of birds accompanying the Skylarks are Starlings, 'Crows,' and Lapwings.

9. *Spring Migration to Northern Europe from the British Isles.*—In mild seasons during the third week of February there are indications at our north-eastern stations that the Skylarks which have wintered with us are beginning to depart for their northern homes, and throughout March, especially after the middle of the month, there is usually much evidence to the same effect, the concomitant species being Blackbirds. Goldcrests, Starlings, Woodcocks, and 'Wild Geese'; but here, again, as in the last case, much escapes notice, and for the same reasons.

The spring emigration from Ireland deserves separate consideration.

Beginning about the middle of February, it becomes more pronounced in March, and ceases with the close of that month. The birds return by the routes taken in autumn and winter, chief of which is that between the south-eastern counties, with Wexford as a centre, and the southern provinces of Wales and shores of the Bristol Channel; while during March there are return flights cross the Irish Sea to North Wales and South-western Scotland. Generally the birds set out after dark, but Skylarks are occasionally recorded as migrating during the day, those from the southern portion of Ireland making for the south-east, while those from the Wicklow coast proceed due east. The night movements are often performed in company with Thrushes, Blackbirds, and Starlings. The winter visitants to the Hebrides leave for the mainland of Scotland about the same time, and call for no special remark.

10. *Spring Passage from Southern to Northern and Central Europe along the British Coast.*—These movements take place during March and early April, and are not easily distinguished from some others that are in progress at the same time. It is probable, however, that the bulk of the Skylarks arriving at this time on the southern coast of England are *en route* for North-western Europe. After reaching this island they move northward along the coast, and finally quit the country in company with those which have been wintering in Great Britain and Ireland, as well as with other emigrants and transient visitors.

THE MIGRATIONS OF THE SWALLOW (*Hirundo rustica*).

The familiar Swallow may be taken as a typical example of a Summer Visitant to the British Islands, whose breeding range reaches a high latitude in Europe, though not extending to the extreme north of the Continent, nor to Iceland. In our islands it is to be regarded, however, not merely as a summer visitant, but also as a Bird of Passage, traversing our shores in spring and autumn on its way to or from its summer quarters in Western Europe. Its winter quarters are known to be in Africa, chiefly to the south of the Great Desert. In preparing the following compendium of its emigrations I have not limited myself to the records furnished by the various Light-stations, since the majority of observations there made do not discriminate between the Swallow and the two species of Martin also visiting our islands; but I have availed myself as well of the voluminous records chronicled in serial literature, often by expert ornithologists.

Spring Immigration of Summer Visitants.—On this subject the records are so numerous and complete as to enable me to speak with authority as to the date of the Swallow's successive arrivals on our shores, and also to trace with some degree of accuracy its gradual spreading over the country, which has hitherto been a *desideratum*. During March a few solitary birds annually appear, sometimes very early in the month, and though these may be regarded as somewhat erratic visitors, no year of the inquiry (1880–87) is wanting in authentic records of their appearance. In all there are twenty-one records of March Swallows, of which ten were observed on the south-west coast of England, four in Ireland, three in the south-east of England, and two each in South-eastern and South-western Scotland. It is not till April that the vanguard of the host reaches our shores, and a careful analysis of dates shows that the average time of its appearance in different parts of our islands is as follows: For South-western England the beginning of the first week; for

Ireland the end of that week; for South-eastern England early in the second week; for South-western Scotland the end of the same; for South-eastern Scotland the middle of the third week; for Northern Scotland the fourth week; and lastly it is not till the second week of May that the few Swallows which resort to Orkney reach their destination. These early immigrants are either single birds or pairs. Some ten or twelve days later than the arrival in each case of this advanced guard takes place the appearance of Swallows in some numbers, and they become gradually abundant throughout the kingdom. These initial hosts are followed by others, and so the influx proceeds during the rest of April and the first half of May, and beyond that date in the case of birds of passage. In backward seasons, such as that of 1887, when cold and unsettled weather with snow and sleet prevailed, the vanguard may be delayed for about a week, but on that occasion its appearance was immediately followed by a 'rush,' and the birds became numerous and general only a little in arrear of their accustomed time. In the Hebrides and North-western Scotland the Swallow is uncommon, and mostly observed on passage in small numbers, while though appearing almost annually in Shetland, chiefly after the middle of May or early in June, it is little more than a straggler. In Ireland the immigrants arrive in considerable numbers until about the middle of May, and in some seasons (1883, 1884, and 1886) so late as the third week of that month, but it is possible that some of these later birds are on passage to the Hebrides and north of Scotland.

It is evident from the statistics consulted that the arrival of Swallows on the western seaboard is well in advance of their appearance further to the east. Not only is this so in the south of England, but even in Scotland the districts of 'Solway' and 'Clyde' almost invariably receive their Swallows several days (some seasons ten or eleven) before the 'Tweed' and 'Forth.'

Swallows are described as arriving on our southern shores during the daytime, chiefly in pairs, but sometimes as many as six or seven together, and flying low over the sea, the immigration lasting most of the day; but they are also noted as coming in small parties, flock after flock, for several hours in succession, and unaccompanied by any other kinds of birds. A remarkable exception to this was, however, observed at the Eddystone in 1887, when from midnight to 3 A.M. on May 3 and 4 hundreds of birds, Swallows and Wheatears, together with (as testified by the wings of the victims) Reed-Warblers, Whitethroats, Wood- and Willow-Warblers, and Redstarts were killed at the lighthouse. Generally, however, few Swallows meet with disaster during their spring journeys, a very small number striking the lanterns, while fewer still seem to suffer from exhaustion.

Spring Passage from the South to Northern Europe.—This movement of Swallows which pass along our coast-line on their way to their homes in the north of Europe does not set in till the last days of April, reaches its maximum about the middle of May, and may be prolonged till nearly the middle of June. Many of the earlier of these transient migrants reach our south coast in company with the Swallows that come to summer with us, but those which pour in during the latter part of May or in June are mostly passengers on their way to Scandinavia.[1] The stream is almost

[1] According to the information of Professor Collett, the Swallow is seldom observed in Norway in April. In the first week of May examples appear singly, about the middle of that month more arrive, and between the 20th and 25th all, perhaps, are come.

wholly confined to our eastern coast, and the North Sea is crossed ere the northern limit of the mainland is reached, for these travellers do not seem to take Orkney or Shetland on their route. A small number of Swallows yearly visit the Hebrides during the first three weeks of May, and it is possibly these birds, or some of them, that find their way to the Færoes,[1] and even as stragglers to Iceland, while others may, perhaps, finally reach Northern Europe by this far western route, which may originate, so far as the British Isles are concerned, on the east coast of Ireland and west coast of England. A few are also observed about the same time on the north-west coast of Scotland.

Autumn Emigration of British Summer Visitors.—During the latter half of July parties of Swallows are recorded as visiting the island stations and lightships off the east coast of Great Britain and the south-east of Ireland, but it may be doubted if such appearances are of much significance, though it may be otherwise with some recorded in 1880, when during the spell of cold weather six flocks of from fifty to sixty each were observed passing to the south on July 27 at the Tees Buoy Lightship, and two days later numbers passed the Leman and Ower Lightvessel, off the Norfolk coast—some alighting, while one struck. But even if these were cases of real migration, it may have been but partial, and the birds merely seeking better quarters within our area. It is not until the last week of August that Swallows ordinarily begin to leave Scotland and the north of England. Then there is a decided movement southward, and, along with Redstarts and Willow-warblers, they are observed at various stations both on the coast and inland. There is no evidence that these birds actually quit the country, and most, if not all, probably tarry for some time in the south of England before crossing the Channel. The Irish movements in August are less pronounced, but the returns show a decided increase of visitors to the coast stations, and indicate the setting in of the ebb. In September the southern movement becomes general throughout the whole country, and reaches its maximum between the middle and end of the month. During its early days there is the first evidence of actual departure from our shores, and the cross-channel emigration then commencing proceeds throughout the autumn. The beginning of October shows a decided falling off in the numbers departing from the northern districts, especially in the west; but the southward movement is well maintained during the first half of the month from the east and south-west of England and the south-east of Ireland. By the middle of the month the emigration from Scotland and the north of England is over, and Swallows observed after that time on the east coast of Britain seem to be the later emigrants from Scandinavia, which since September have been passing along that coast, mingling with our own birds, so that in many cases the two movements are indistinguishable. After the middle of October a considerable diminution is observable, except on the coast of the Channel, where the efflux is maintained throughout the month. During the first half of November stragglers are still to be seen on the east coast of Great Britain and the south-east of Ireland, but there are no records of observations in the west of Scotland, and very few from the north-west of England. From the south of England many departures occur annually till the middle of the month, while stragglers are to be

[1] Herr Knud Andersen informs me that the Swallow appears not uncommonly in the Færoes in May.

seen later, especially in the south-west. December Swallows are *raræ aves*, and were only observed in one year of the inquiry. The autumn of 1880 was remarkable for the protracted stay of the *Hirundinidæ*, and a few belated Swallows were recorded on the south coast of England in the last week of November, while in December one was observed at Bournemouth on the 7th, and two at Eastbourne, and one at Woolmer on the 11th, the weather until that time having been mild.[1]

Autumn Passage along the British Coast from Northern Europe.—The return of the Swallows which have summered in Scandinavia (accompanied by their young), and their passage along our coast, usually takes place from the middle of September [2] onwards, the 9th of that month (in 1884) being the earliest day on which their movement is recorded. The passage is well maintained during the rest of the month, and is prolonged by a few birds to the first or even second week of October. Some of these travellers from the north are perhaps induced by our milder climate to tarry, and it is possibly such laggards that occur on or near our east coast in November, and thus account for the lateness of migration there observable when compared with the west coast. It has been already remarked that, after their arrival on our shores, Swallows on autumn passage mix with our native birds then emigrating, and it is no longer possible to trace the former, though they doubtless form the bulk of the rear-guard movements of the autumn. In Shetland and Orkney there is no appearance of these returning Swallows of passage, and but feeble evidence of their taking the Hebrides on their way, though the records indicate such a transit during September and the first day of October. There are passage movements on the part of Irish birds discernible in the the south-west of England to the third week of October, with occasional stragglers to the middle of November. In September of some years Swallows are recorded at the lightships off the mouth of the Thames and the Kentish coast as coming from the south-east, and occasionally in considerable numbers.

Further Observations on the Autumn Movements.—At the best stations for observing emigration it usually takes the form of the continuous passage of small parties, not exceeding a score, and as this may last for hours vast numbers thus depart. They have, however, been observed on the south coast to assemble in thousands and fly away *en masse*, but this is only occasionally recorded. Swallows are frequently seen to emigrate in company with House Martins and occasionally with Sand Martins. The earliest troops to cross the channel are observed to be composed of old and young birds. It has, however, been noticed that the large congregations at various points on the south coast, whether preparing to emigrate or in actual movement, consist in many cases chiefly or entirely of young birds, but in others wholly of adults. More frequently, however, the number of old birds is in normal proportion to that of the young. The time of the day at which emigration takes place seems equally varied. On the south coast some of the great movements are recorded as in

[1] Mr. Joseph Agnew, light-keeper, states that a Swallow was caught on the Monach Isles (with the exception of St. Kilda, the outermost of the Hebrides) in January 1887, but he unfortunately furnished no further particulars of the occurrence.

[2] Professor Collett states that Swallows begin to leave Southern Norway the first week of September, and that he has known individuals to remain there so late as the middle of October.

progress from early morning to noon, others as going on until night sets in.[1] During the autumn and spring migration (though concerning the latter we lack definite information) the English Channel is probably crossed by many routes, but there are certain much-used points of departure to reach which the birds shape their course. Beginning in the west, we find among them the Land's End, the Lizard, the Eddystone, and Start-Point. It is otherwise, however, on the Dorset and Hampshire coasts, along which Swallows are recorded as proceeding to the eastward, and it is not until the Nab Lightvessel is reached that the flight becomes southerly towards the French coast. In Sussex, too, the flight is easterly towards Beechy Head, just before arriving at which many birds cross the Channel.[2] Others still pursue their easterly flight, and finally cross the Straits of Dover. There may be other routes taken, but the points of departure just named are those which result from the present inquiry. There are, however, some records of Swallows occasionally moving westward along the south coast. If this should be more than accidental, a cross-movement of departing birds occurs then. The shore line is closely followed by many of the Swallows moving south, especially by those which are on passage.

Investigations made at the Marine Biological Laboratory, Plymouth.—Report of the Committee, consisting of Mr. G. C. BOURNE (*Chairman*), Mr. W. GARSTANG (*Secretary*), Professor E. RAY LANKESTER, Professor SYDNEY H. VINES, Mr. A. SEDGWICK, *and* Professor W. F. R. WELDON. (*Drawn up by the Secretary.*)

THE British Association's table has been occupied during the past year by the following naturalists, who devoted themselves to investigations or to the collection and preparation of material for research on the subjects mentioned :—

Mr. R. C. Punnett, August-September 1900 (two months) : On the Pelvic Plexus of Elasmobranchs, and on the Anatomy of Nemertines.

Mr. S. D. Scott, August 1900 (one week) : On the Excretory Processes of Ascidians.

Dr. F. W. Gamble, April 1901 (one week) : On the Histology and Physiology of Mysis.

Mr. W. B. Randles, July-August 1901 (one month) : On the Anatomy of Trochus.

Mr. W. M. Aders, August 1901 (two weeks) : On the Spermatogenesis of Cœlenterata.

Dr. Gamble's work was unfortunately cut short unexpectedly by private causes, and another gentleman, to whom the table had been allotted—

[1] At the Nab Lightship, October 1, 1886, Swallows are recorded as passing south at intervals, twenty at a time, from dawn to dark. The returns from Hanois Lighthouse, on the west coast of Guernsey, show that Swallows pass southward from 6 A.M. to 8 P.M. At the Casquets, west of Alderney, on October 1, 1880, Swallows, with other birds, Song-Thrushes, Ring-Ousel, Land- and Water-Rails, and a Woodcock, occurred from 11 P.M. to 3 A.M.: 200 Swallows struck the lantern. The movements at this station, however, may possibly have nothing to do with migration on the British coasts.

[2] When crossing between Newhaven and Dieppe in September I have seen Swallows passing in a south-easterly direction towards the French coast.

Mr. Chubb, of University College, London—was also prevented eventually from making use of it.

In spite of these circumstances, which prevented the utilisation of the table to the full extent, researches of a substantial character have been carried out. Part of Mr. Punnett's work, 'On Two New British Nemertines,' which has been published recently,[1] and Mr. Aders' researches on Spermatogenesis, on last year's material, have been submitted and accepted by the faculty of the University of Marburg as a thesis for graduation. Mr. Randles' report is given below.

The Committee respectfully request re-election; but in view of a balance of 8*l.* 5*s.* remaining unexpended, they apply only for a grant of 10*l.*, in addition to the balance in hand.

On the Anatomy of Trochus. By W. B. RANDLES.

I occupied the British Association table from July 17 until August 17, 1901, during which time I was engaged in collecting and preserving material for a research on the anatomy and histology of Trochus.

Several species of Trochus are to be found either at or in the vicinity of Plymouth, and are representatives of three sub-genera, viz.—

Trochus (Gibbula) cinerarius.
" " umbilicatus.
" " tumidus.
" (Calliostoma) zizyphinus.
" " striatus.
" " granulatus.
" (Trochocochlea) lineatus.

An examination of the internal structure of Trochus shows the close relationship which evidently exists between this genus and Pleurotomaria, the anatomy of which has recently been described by Woodward.[2]

Especially is this noticeable in T. (Calliostoma) zizyphinus, where, save for the presence of only one gill, the internal structure is almost identical with that of Pleurotomaria. The nervous system is, however, more highly differentiated, there being a nearer approach to concentration of nerve cells into ganglionic masses than obtains in Pleurotomaria.

I have compared the various species of Trochus anatomically with a view to testing the validity of the division into sub-genera.

Though the number of species obtainable here is not very large, yet I find that, as regards the sub-genera Gibbula and Calliostoma, definite anatomical differences do occur, which justify the separation of these forms into sub-genera.

Trochus (Trochocochlea) lineatus, however, presents no apparent anatomical differences from the various species of *Gibbula*; and though the examination of a single species of this sub-genus is scarcely sufficient to enable one to judge of its validity or not, yet a very close relationship evidently exists between *Gibbula* and *Trochocochlea*. I hope shortly to publish the results of my investigation on this genus.

In conclusion I beg to thank the British Association for the use of their table and to express my indebtedness to Dr. Allen for his many suggestions and ever-ready help.

[1] *Quart. Journ. M. Science*, vol. xli. part 4, pp. 547–564. Two plates.
[2] *Q.J.M.S.*, March 1901, pp. 215–268.

Some Notes on the Behaviour of Young Gulls artificially hatched.

By Professor J. ARTHUR THOMSON, *M.A.*

[Ordered by the General Committee to be printed *in extenso.*]

THE biological and psychological interest of the observations made by Professor C. Lloyd Morgan and others on the behaviour of artificially hatched young birds (especially chicks) led me this summer to utilise an opportunity which presented itself of incubating some eggs of *Larus ridibundus* and of observing the behaviour of the young. I had also wished to obtain material for testing the influence of different kinds of diet on the texture of the stomach, but this problem was not followed up. Although my observations are not in any way surprising, they raise a number of interesting questions; and it is, of course, well that we should contrast the ways of a thoroughly wild bird with those of the chick, which has probably been to some extent changed by domestication.

Some of the gulls which I hatched in my laboratory were given to Dr. Lewis MacIntyre, lecturer on comparative psychology in the University of Aberdeen, and I am indebted to him for confirmation and extension of certain facts which I noticed. But, as he has not seen this communication, he is not in any way responsible for errors of inference which may have crept in. I should also notice that four newly hatched birds from different nests were used for comparison with those that were artificially incubated.

Among observations made on repeated occasions at the gullery the following may be noted, though they may be familiar to many. Although the thousands of birds are extraordinarily quick to take alarm—generally, to human perception, quite needlessly—they acquiesce in two or three minutes to the presence of an intruder in a boat, if he sit still under a covering of sacking. The birds will then come within arm's length and settle down, though the shape of the observer who is peering through holes cut in the sacking forms the most conspicuous object in the immediate environment. By this method it was possible to make sure of the fact that the same bird comes back to the same nest. As there may be hundreds of nests within a small radius—at least half-a-dozen on the area of an ordinary household dining table—and as the very uniform bank of mud, tussocks, and bog-bean stems presents to our eyes few distinctive marks, and as there is continuous rising, squabbling, and resettling, it seemed well to take some pains to fix attention on birds with some slight peculiarity of plumage, and to prove that they came back to their proper nest. The extraordinary variability of the coloration of the eggs—from unspotted pale blue to very dark brown with darker spots—may facilitate the recognition of the nest during the day. On one occasion I observed that a very young nestling of the first or second day which had tumbled out of its own nest and crawled to the next one was accepted without demur. Older youngsters, able to run about, are pecked at very viciously when they come near a brooding bird.

First Day.—Observations in regard to behaviour immediately after artificial hatching were greatly hindered by the fact that the young birds are so imperfectly warm-blooded. Something of the nature of a hothouse would be useful. When the young creatures were taken from the incubator or from a warmed box they were in a few minutes oppressed with cold, and uttered their cry of discomfort almost continuously. As observations under conditions of discomfort did not seem of value, the birds were at first studied only for a few minutes at a time.

Hatched with open eyes, which did not wink on the approach of a finger, the young birds showed no sign of any fear. A notable fact is their extraordinary self-possession throughout, though suspiciousness gradually grows on them.[1] They pecked within a few hours after hatching both at finger and spoon, with or without food, but with a lack of precision. They also pecked at the cotton-wool of their beds. Many of the first day's peckings missed, but the learning was very rapid. It was observed that in precision of early pecking the young gulls were far ahead of young coots. Even on the first day some fed repeatedly and heartily, but this varied with the individual.

Some preening was observed on the first day, and the general vertebrate action of raising the hind foot to scratch the head—seen in frog, lizard, chick, kitten, &c.—was frequently noticed. Almost from the first, too, there was a slight use of the wings in balancing.

On the first day one turned its head towards the cheep of another in a separate compartment of the incubator and cheeped as if in response; a third, still within the egg (chipped), often uttered a note, twice repeated, when the others did. Little or no attention was paid to noises, except to a prolonged low whistle, which was followed by cowering, even on the first day.

Second Day.—On the second day the pecking was vigorous and precise: the birds followed bright objects by moving the head and neck, and pecked at them in motion. They attended to sleeve-links, ring, silver spoon, &c.; they looked up or cheeped when I tapped at the window of the incubator, but they took no heed of snapping fingers, ring of spoon on a glass beaker, rubbing of cork on glass, and many other striking noises. They shrank a little from a sharp hand-clap close to them, but did not cower. A prolonged low whistle again made them crouch in silence, but after a number of trials on the same day (second) one of them entirely ceased to attend to it. It would be interesting to discover if there is in the normal environment some alarming sound corresponding to the prolonged low whistle, but I cannot make any plausible suggestion which would apply to the gullery observed. Later on there was obvious association of certain sounds with the advent or discovery of food.

The sensitiveness to cold—which repeatedly led to a reduction in the number of young birds—was still very marked on the second day. Even on a rug before the fire one would creep into my hands or crawl up my sleeve, apparently for warmth. At the pond many young birds seemed in a state comparable to cold-coma, and it may be suggested that this will tend to prevent premature excursions, which would in many cases inevitably land the young birds in the water. A gentle pecking under shelter, *e.g.*, of trouser-leg, suggested pecking at the mother's coverts.

As is well known, the adults are very combative, and it was interesting to observe a fight early on the second day of life. Beth pecked at Aleph's bill, Aleph responded, and there was a combat so forcible that separation seemed advisable. It was interesting in connection with these youthful combats to notice the interlocking of the bills just as may be observed in adults. As has been pointed out, these bill-wrestlings are of biological

[1] I may note here that in early days the presence of cat or dog does not seem to excite any attention; later on there is alert attention, but no apparent fear: a gull two to three weeks old will run at a fox-terrier and peck its nose; but later on, before they fly off, when about a month old, the birds utter the alarm cry and retreat on the sudden appearance of a cat or dog.

interest in connection with the regeneration of injured beaks in birds. I cannot suppose that this second-day combat was other than an early expression of the combative instinct; it could hardly be due to hunger, for I have noted in regard to Aleph and Beth, between their first and second days, that they were fed at 3.30 A.M., at 6 A.M., at 9.30 A.M., and so on till 6 P.M. They would only take a little at a time, but that greedily enough. I suppose the mother must give them mouthfuls with great rapidity, for I entirely failed to see a single case of feeding at the gullery, and others have been equally unsuccessful. Between 7 and 8.30 P.M. on May 24, between 3.30 and 7.30 A.M. on the 25th, along with a careful observer to whom I am much indebted, I watched the nests in the hope of detecting the feeding process, but quite in vain.

Third Day.—On the third day one of them had a bath, and showed the completeness of the cleaning instinct. The head was ducked sideways, shaken about, and reducked precisely in adult fashion, and this on first experience of water, and of course without any example. After some cleaning the bird drank in the usual chick fashion.

Another, Omega, on its third day was put into a deep bath: it screamed for a few seconds, then settled down to paddling in a thoroughly efficient fashion, but with a tendency to swim backwards. It washed its head thoroughly, cleaned its bill with its foot, turning round and round in the water like a top, and after the bath it preened itself. Repeated experiments with different birds showed perfectness of swimming powers without experience or imitative stimulus; also perfect preening after the bath.

In several cases the bath was followed by extreme weakness, by convulsive fits, by inability to stand upright—also observed in fatigue (the whole tarso-metatarsus being horizontal)—and by a physiologically interesting tendency to run rapidly backwards and then collapse. After various treatments—warm milk, a little oil, massage, and drying before the fire—there was rapid restoration to normal vigour. I should, of course, like to know what the backward movements really mean. They are not to be confused with the normal backward run of 6–9 inches before defæcation, which is doubtless in part an instinctive adaptation to avoid filing the nest, though perhaps also with some internal functional import.

Omega in its third day was fighting with X of two days, cowered down into a corner when I hissed vigorously: it was far more frightened than any other I observed. Again, one would like to know what the hiss corresponds to in the normal environment. The same bird Omega fought on the same day with Y (a day younger) with the bills gripped in the adult fashion.

My observations made at odd times in a busy summer session cannot be taken so seriously as the careful studies by Lloyd Morgan and others, but they left me with the general impression that the wild bird is in some respects more endowed at birth than the cleverest chick.

For instance, while we know that Lloyd Morgan's chicks would gorge themselves with useless or hurtful things, such as worms made of red worsted, the young gulls were from the first judicious in their eating. During the first two days they got some of the cotton-wool of their bed into their mouths, but this was inevitable; they often pecked at little pieces of dry excrement, just as they pecked at any conspicuous spot, such as a letter on a piece of paper, and so persistently at spots on the saucer that it seemed advisable to give some of the youngest an unspotted saucer.

Once or twice I saw one peck at a flame, but as far as I could see they never swallowed anything injurious or useless. They would test particles of tobacco, for instance, with an exceedingly rapid touch, but they never went beyond testing. The same was true of young coots. I tried X repeatedly with a little twisted roll of paper: he pecked at it three times after much provocation, but he threw it away each time, and beside this we have to place the fact that they ate worms in the garden and small insects without any hesitation the very first time. A heavy meal of a particular sort seemed to be followed by repugnance to the same food next day; they showed that repentance which is 'the weight of undigested meals ate yesterday.' Thus I note that 'Alpha and Beta ate too much fish yesterday, won't touch it to-day, but take liver freely,' and similarly with many other food-stuffs. Noteworthy achievements were catching a flying insect and breaking an earthworm into three pieces.

As to quickness of learning, I observed that of two nestlings who were having their first experience of food in a saucer, the elder after some food had been given to it pecked of itself, while the younger pecked at first only at the bill of its senior, but within five minutes pecked also out of the saucer.

As to sounds, it seemed possible to distinguish (*a*) the peep-peep uttered before birth and long afterwards when they were not completely comfortable. The same is heard at the gullery when the mother has been off the nest for some time; sometimes in my specimens it would not be once heard for fifteen minutes or more. It means cold, hunger, or some discomfort. (*b*) Secondly, there is a deeper, more adult-like dissyllabic quack uttered in excitement before food. (*c*) Thirdly, a sharp surprise cry uttered when they were lifted quickly into bright light, or disturbed. (*d*) Fourthly, there is a very plaintive, but contented, almost sigh-like cheep, often when very comfortable.

One thing the young gulls seemed to have to learn in their artificial environment was to recognise water to drink, but this was probably because it was presented to them not quite normally—in saucers, glass vessels, and shallow bath. Although thirsty, they would walk round, or even at first through, a saucer without using their opportunity. As with Lloyd Morgan's chicks they drank if they got their bills wet by pecking while standing in the water, and they also drank when thrown into water. Only after ten days' education did one of them go at once to a dish of water placed on the floor and drink. I conclude that an artificial association was established between a shining surface and drink, for I have seen my gulls of three weeks or so trying to drink from the glass lid of a pasteboard specimen box placed on the floor.

Another general impression I got was that the kin-instinct is strong. There seems to be even from within the egg a responsive piping to those outside. On the first day Beth tried to make towards Aleph in a separate compartment of the incubator; an older bird showed the greatest complacence towards its younger companion who followed it about and often tried to snuggle under its imperfect wing; when one, before having its first bath, tumbled from the floating cork raft into the water, and was for a moment confused and screamed, his companion, who had experience of two previous baths, jumped after the first, swam to him, and touched him; where two strangers were brought together for convenience of warmth, there was in one case amity after a few bill-peckings; in another case they were not seen nestling together till the third day; in two cases

when the older gull had taken flight into freedom leaving a younger companion in the garden, the first to fly returned repeatedly to visit the younger until it also flew; adults of the species flew about overhead when the young in the garden were approaching their time for flight. On the other hand, a winged herring gull (shot by some careless person) which lived in the garden displayed not the remotest interest in its small congeners. Nor were young coots interested in young gulls.

The widespread following-instinct was very marked between younger and older; indeed, to find one in a large room in the summer twilight the quickest way was to set loose another, and it should also be noticed, in confirmation of some remarks by Thorndike, that one of the young gulls used to follow a little boy's bare feet persistently over the lawn, nestling beside them when he stood still.

Finally, it may be noticed that while there was for three to four weeks great tameness and familiarity on the part of the young gulls, the wild shyness and suspicion grew quickly after they were able to rise from the ground. The species is of course migratory, and there seemed to be a growing restlessness towards the end of July, but this may have been prompted by adults who frequently flew round and round overhead. It was noteworthy, however, that there was a return of tameness on the part of a younger bird after the flight of the older. It was even seen to thread its way through a group of children seated on the lawn, and coolly appropriate a strawberry from one of the plates.

Changes of the Land Level of the Phlegræan Fields.—Report of a Committee consisting of Dr. H. R. MILL (*Chairman*), Mr. H. N. DICKSON (*Secretary*), Dr. SCOTT KELTIE, *and* Mr. R. T. GÜNTHER. (*Drawn up by* Mr. R. T. GÜNTHER.)

WORK was commenced soon after my arrival in Naples at the end of June 1901, and is still in progress.

I am very glad to be able to report that the material for investigation is even more abundant than I anticipated when the research was proposed as a desirable one a year ago. Many of the so-called rocks and shoals along the coast of Posilipo have proved to be really artificial constructions, Roman breakwaters and foundations, and walls of houses.

So far as I am aware, these constructions, now submerged to varying depths, have never been mapped; nor indeed is there a good large scale map of the coast upon which the submarine antiquities could be plotted. I have therefore had to devote a good deal of time to the preparation of a new survey of the coast line before beginning to map the adjacent portions of the sea bottom.

The sites to which I have devoted most attention are:

1. A triangular area inside the Pietra Salata, south of the Capo di Posilipo. Here the remains of a large house or houses have been discovered.

2. The ancient harbour of Marechiano, famed as the traditional site of Pollio's fish tanks.

3. The Gaiola region and Trentaremi Bay. To the north-east of the Gaiola is a Roman harbour, which seems to have altogether escaped the notice of modern archæologists. It is sheltered on the south by a series of piers (now entirly submerged) very like those of the Roman harbours of Nisida, Pozzuoli, and Miseuum.

It is unfortunate that this material, being submerged, will take a long time to work out completely; were it above water a clear idea of its significance would be sooner obtained.

So far as the work has gone at present, it tends to show that the land level in Roman times was about 15 feet higher than at present; that there was a road all along the coast of Posilipo underneath the cliffs; and that this road was lined by numerous houses, most of which have been washed away. These points and others will be shown on a map which is in preparation.

The Climatology of Africa.—Tenth and Final Report of a Committee consisting of Mr. E. G. RAVENSTEIN (*Chairman*), Dr. H. R. MILL, *and* Mr. H. N. DICKSON (*Secretary*). (*Drawn up by the Chairman.*)

METEOROLOGICAL returns have been received by your Committee in the course of last year from twenty-one stations in Africa, including Asiut and Omdurman: Old Calabar; Blantyre, Lauderdale, Fort Johnston, and Nkata Bay in Nyasaland; Kisimayu, Malindi, Lamu, Takaunga, Mombasa, and Shimoni on the coast of British East Africa; Machako's, Kitui, Nairobi, and Kikuyu in the interior of that Protectorate; and from the four lake stations in Buganda. We are, moreover, enabled to give the results of seven years' observation on the rainfall at Mengo (Buganda), taken from the unpublished journal of the late Mr. A. M. Mackay. A table giving the rainfall since 1890 at a number of stations has been added.

Since the appointment of your Committee in 1891 meteorological reports from as many as seventy-one African stations have been published through its agency, and it may safely be asserted that many of the more valuable of these observations would never have been made or become generally available had it not been through our action. Amongst these stations, however, there are only fifty-six the records of which embrace a full year, and eleven from which we have received full returns for at least five years. These latter are Lauderdale, Dunraven (rainfall only), Kisimayu, Malindi, Lamu, Takaunga (rainfall only), Mombasa, Chuyu (or Shimoni in Wanga), Machako's, Fort Smith (in Kikuyu), and Mengo (Namirembo and Natete). Among stations having a less extended record, but distinguished for the care with which the observations were taken and the interest attaching to the results, are Bolobo in the Congo State (3¾ years); Zomba (4 years) and Fort Johnston (28 months) in Nyasaland; Kibwezi (18 months) in British East Africa and Old Calabar. We should also refer here to the high value attaching to the observations on the lake level of Victoria Nyanza.

A summary of Dr. Livingstone's meteorological work during his last journey (1866–71) will be found in our report for 1894.

In *Egypt* Major Lyons, Director General of the Survey Department, is gradually pushing meteorological stations into the Sudan.

In *Nyasaland* the scientific department has been organised by Sir H. Johnston and placed in charge of Mr. McClounie, an able and zealous officer, who during a recent visit to Europe has availed himself of opportunities offered to gain a competent knowledge of the working of a thoroughly equipped meteorological observatory. Zomba, the headquarters of the Protectorate, will soon take its place among stations of the first order, for

it is now furnished with a thermograph, a barograph (specially designed for a considerable altitude), an anemometer, and a Whipple-Caselle sunshine recorder. Fort Johnston ranks as a station of the second order, and it is proposed to establish similar stations at Chinde and at one of the lake ports. In addition to Lauderdale, where the representatives of Mr. J. W. Moir continue his work, Zomba, and Fort Johnston, there are ten climatological stations, and rain-gauges have been set up in many places. Quite recently ten hygrometers have been ordered, for, as Mr. McClounie writes, 'cacao is to be experimented with, and to think of growing such a product anywhere we must have some idea of humidity and saturation.' The registers are kept in conformity with our 'Hints.' The results are published monthly in full as a supplement to the 'British Central Africa Gazette' and freely distributed.

In *British East Africa* instruments were supplied in 1891 by the late Imperial British East Africa Company, and it does not appear that fresh grants have been made since or breakages made good. The earlier records appear to have been lost, but a summary of all that could be saved up to 1893 has been published by the Chairman of your Committee.[1] All that has been done since will be found in the 'Reports' of your Committee, the original 'Registers' having been kindly communicated by the Foreign Office.

In July 1895 Dr. A. D. Mackinnon proposed to H.M. Commissioner for *Buganda* the establishment of at least three fully equipped meteorological stations, there existing at that time throughout the Protectorate only two rain-gauges, in addition to a few instruments in the hands of the missionaries. These sets, including mercurial barometers and anemometers, were granted by the Foreign Office in May 1896, and supplementary grants have been made since. When Sir H. H. Johnston arrived at the close of 1899 he found Mr. Alexander Whyte at the head of a scientific department, and he induced the Foreign Office to appoint an assistant (Mr. J. Mahon), who should attend more particularly to the collections and the tabulation of meteorological information. Meteorological stations have now been established at Naivasha, Baringo, Eldoma Ravine, Kisumu, Mumias, Jinja, Fort Thruston, Kampala, Ntebe, Fort Stanley (Sese Islands), Masaka (Buddu), Fort Portal (Toro), Mbarara (Ankole), Hoima (Unyoro), Wadelai, and Gondokoro.

Such of the instruments originally issued by us which have not become unserviceable, been lost, or been otherwise disposed of have been left in the hands of trustworthy observers, with a reversionary claim upon them by the British authorities within whose territory the stations are situated.

Your Committee have likewise published 'Hints to Meteorological Observers in Tropical Africa,' which, they are happy to say, have been made widely known and freely accepted by observers. Copies may be obtained on application to the Secretary of the Royal Meteorological Society.

The registers received by your Committee, and not claimed by the observers, have been handed over either to the Meteorological Council or

[1] 'Report on Meteorological Observations in British East Africa for 1893.' London: G. Philip & Son, 1894. Persons interested can have copies gratis on application.

to the Secretary of the Royal Meteorological Society, and may be freely consulted by persons interested.

Your Committee are under no illusion as to the merely conditional value of many observations published by them. The index errors of the instruments were unknown in many instances; the hours for making observations were injudicially chosen; the observers, owing to illness or official duties, were frequently unable to fill up the registers, and there was no one to take their place; or, worse still, they had absolutely no knowledge of the manner in which the instruments entrusted to them should be handled, and placed readings on record which, on the face of them, are utterly absurd,[1] and must unhesitatingly be rejected.

Your Committee, on bringing their ten years' service to a close, desire to direct the attention of the authorities called upon to organise the meteorological service in British Protectorates or Crown Colonies to the following points:—

1. The instruments supplied should not only be verified before they leave England, but should also be inspected periodically by a competent official, who would pay particular attention to their exposure, inquire into the competency of the persons charged with filling in the registers, and eventually teach them how to observe.

2. Inasmuch as all officials may occasionally be called upon to fill up the registers, they should be instructed, before they leave England, in handling and reading the usual meteorological instruments. An hour spent at the office of the Meteorological Council, or with the Secretary of the Royal Meteorological Society, would suffice for that purpose.

3. It is of far greater importance to have a limited number of stations well equipped, and the registers from which can be thoroughly trusted, than a multiplicity of stations provided with defective instruments, carelessly or intermittingly attended to.

4. Care should be taken that there should be no interruption in the records kept at the principal stations owing to the illness or temporary absence of the observer. Duly qualified native assistants could be obtained from the Meteorological Department of India.

5. It is most desirable that the hours of observation recommended in our 'Hints' should be strictly adhered to, not for the sake of uniformity only, but mainly because they yield a true mean of barometric pressure, temperature, and humidity without making undue or unreasonable demands upon the time of the observers.

6. Unless local provision is made for the adequate publication of the observations, the registers should be forwarded (through the Foreign or the Colonial Office) to the Meteorological Council, or to the Secretary of the Royal Meteorological Society, in order that abstracts may be prepared and made generally accessible to meteorologists and others interested. Still better would it be if an annual volume containing all these observations were to be published separately.

[1] Not infrequently, as pointed out by us in publishing these observations, the wet bulb and maximum thermometers give higher readings than the dry bulb and minimum thermometers. Nay, some of these observers seem to be ignorant of the decimal notation, for they enter 17·8 or 30·68 when there is no doubt that 17·08 and 30·068 ought to have been entered.

Asiut (Egypt), Lat. 27° 11′ N., Long. 31° 13′ E. Height of Barometer above Sea-level 55·6 m. Abstract of Monthly Return, Published by Major J. S. G. Lyons, R.E., Director-General of Survey Department, Cairo.

Month	Mean Atmospheric Pressure	Temperature (Celsius)					Relative Humidity				Vapour Pressure				Cloud 0–10 Mean	Prevailing Wind			Rain		Evaporation
		Mean Max.	Mean Min.	Mean	Extremes Max.	Extremes Min.	6 A.M.	2.30 P.M.	9 P.M.	Mean	6 A.M.	2.30 P.M.	9 P.M.	Mean		6 A.M.	2.30 P.M.	9 P.M.	Amount	Days	
1900	mm.	°	°	°	°	°	P.c.	P.c.	P.c.	P.c.	mm.	mm.	mm.	mm.					mm.	No.	mm.
May	758·3	38·7	20·2	29·0	46·0	15·0	38·0	11·0	22·0	24·0	11·7	13·6	13·1	12·8	2·9	N.W.	N.W.	N.W., N.E.	0	0	—
June	757·0	38·4	21·6	30·6	47·5	17·5	47·3	13·8	23·0	28·0	15·0	17·8	15·5	16·1	2·7	N.W.	N.W.	N.W.	0	0	462
July	753·9	38·3	23·3	31·5	44·0	15·5	52·0	16·6	21·0	30·9	12·3	7·8	8·3	9·5	0·1	N.W.	N.W.	N.W.	0	0	—
							8 a.m.		9 p.m.		8 a.m.		9 p.m.			8 a.m.	—	9 p.m.			
August	754·6	37·7	23·1	30·4	42·5	22·0	48	—	42	—	13·2	—	13·5	—	0·2	N.W.	—	N.W.	0	0	362
September	757·5	32·2	20·3	26·2	36·0	18·0	66	—	55	—	13·6	—	14·3	—	0·5	N.W.	—	N.W., N.E.	0	0	280
October	759·6	30·2	17·2	23·7	36·5	14·0	71	—	—	—	13·5	—	—	—		N.W.	—	N.W.	0	0	—
November	760·4	27·3	11·4	19·3	31·0	7·0	71	—	67	—	10·0	—	9·9	—	1·0	N.W.	—	N.W.	0	0	126
							8 a.m.	2.30 p.m.	9 p.m.		8 a.m.	2.30 p.m.	9 p.m.			8 a.m.	2.30 p.m.	9 p.m.			
December	761·2	22·4	8·3	15·3	28·0	3·0	78	46	70	65	7·8	7·8	8·0	7·9	3·5	N.W.	N.W.	N.W.	0	0	90
1901																					
January	762·1	19·9	4·6	10·1	23·0	0·5	73	56	68	66	6·4	7·6	6·4	6·8	2·7	N.W.	N.W.	N.W.	0	2	86
							8 a.m.	2 p.m.	8 p.m.		8 p.m.	2 p.m.	8 p.m.			8 p.m.	2 p.m.	8 p.m.			
February	760·5	27·0	8·0	15·6	34·0	5·0	73	35	64	51	8·2	8·4	8·3	8·3	1·4	N.W.	N.W.	N.W.	0	0	118
March	759·1	32·3	10·9	19·1	42·5	4·0	59	21	49	43	8·1	6·7	8·1	7·6	1·8	N.W.	N.W.	N.W.	0	0	226
April	753·1	32·6	14·8	22·5	44·0	10·0	50	21	33	33	8·2	6·6	7·7	7·5	7·5	N.W.	N.W., N.E.	N.W.	0	0	201
May	755·3	34·4	17·7	25·5	44·0	13·0	36	19	28	28	8·4	7·0	7·1	7·5	3·1	N.W., N.E.	N.W.	N.W.	0	0	333
Year (June to May)	757·9	31·1	15·1	22·2	47·5	0·5	60	—	48[1]	—	5·3	—	3·8[1]	—	2·1[1]	N.W.	N.W.	N.W.	0	0	—

Asiut.—The mean temperature from May to July, 1900, is deduced from the formula $\frac{6+2.30+9+9}{4}$; that from August to the end of the year from the formula $\frac{\text{Max.}+\text{Min.}}{2}$; that since January 1901 from the formula $\frac{8+2+8+\text{min.}}{4}$.

The Barometric Pressure has been reduced to 1° C., to sea-level and to latitude 45°. The means, however, are merely approximate, having been deduced from observations made twice or thrice daily, at 8, 2.30 and 9, or at 8, 2 and 8, or at 8 and 9, or at 8 a.m., 2.30 p.m. and 9 p.m. (May to July, December and January), 8 a.m. and 9 p.m. (August to November), or 8 a.m., 2 p.m. and 8 p.m. (since February).

There is a self-recording aneroid at the station, as also a thermograph, but the records of the latter seem to be untrustworthy.

The Humidity for December to May is in all probability greater than stated above.

[1] Partly estimated.

Omdurman (Sudan), Lat. 15° 28′ *N., Long.* 38° 30′ *E. Height of Barometer above Sea-level* 376 *m. Abstract of Monthly Returns, Published by Major J. S. G. Lyons, R.E., Director General of Survey Department, Cairo.*

Month	Mean Atmospheric Pressure	Temperature (Celsius) Mean Max.	Mean Min.	Mean	Extremes Max.	Extremes Min.	Relative Humidity 8 A.M.	2.30 P.M.	9 P.M.	Vapour Pressure 8 A.M.	2.30 P.M.	9 P.M.	Cloud 0–10 Mean	Prevailing Wind 8 A.M.	2.30 P.M.	9 P.M.	Rain Amount	Days	Heaviest Fall
	mm.	°	°	°	°	°	P.c.	P.c.	P.c.	mm.	mm.	mm.					mm.	P.c.	mm.
1900 July (8–31)	723·6	25·9	21·5	29·8	39·0	21·1	71	37	58	17·8	14·3	17·2	5·2	S.W., S.	S., S.W.	S., S.E.	80·0	4	56·4
August	724·1	35·7	23·3	29·9	39·0	18·9	76	39	61	18·6	15·7	18·9	3·7	S.E., S.	S.E.	S., S.E.	56·4	3	27·6
September	724·0	38·2	24·8	32·7	42·0	21·1	67	35	51	17·3	15·3	17·0	2·2	S.W., N.W.	S., S.E.	S.E., S.	22·5	2	12·5
October	723·7	39·6	21·3	32·4	42·0	18·3	41	17	26	10·5	8·6	9·2	0·9	N.E., N.	N.E.	N.E.	7·6	2	5·3
November	725·0	35·5	20·8	25·9	41·0	16·1	29	15	18	5·3	6·1	5·1	0·6	N.	N.E., N.	N.	0	0	—
December	726·3	30·2	17·9	23·1	36·0	13·0	31	22	23	4·8	6·3	5·1	1·1	N.	N., N.W.	N.	0	0	—
							8 a.m.	2 p.m.	8 p.m.	8 a.m.	2 p.m.	8 p.m.		8 a.m.	2 p.m.	8 p.m.			
1901 January	726·6	28·0	17·0	22·5	38·0	12·0	28	17	21	4·9	5·2	4·8	0·8	N.	N., N.E.	N., N.W.	0	0	—
February	724·4	31·7	21·2	26·3	39·0	14·0	31	15	21	7·1	5·8	5·8	0·1	N.	N.E., N.	N.	0	0	—
March	723·2	37·6	—	27·7	42·0	—	23	11	15	6·0	6·1	5·2	0·6	N.E., N.	N.E., N.	N., N.E.	0	0	0
April	722·5	39·8	—	29·8 [1]	44·0	—	17	15	12	4·6	6·4	4·6	1·1	N.N.E., N.E.	N.E., N.	N.E., N.W.	—	—	—
May	721·8	42·4	26·1	33·9	44·0	18·0	21	11	15	8·45	7·38	6·70	1·0	N.N.E., S.	N.E., N.	N.E., N., N.W.	0	0	—

Omdurman.—The Barometric Pressure has been reduced to 0° C., but not to the sea-level or lat. 45°.

The mean temperature up to December is deduced from the formula $\frac{6+2.30+9+9}{4}$; that beginning with January 1901, from the formula $\frac{8+2+8+\text{min}}{4}$.

[1] Estimated.

l Calabar. Lat. 4° 58' W., Long. 8° 17' E. Observers: Dr. E. G. Fenton and Dr. Robert Ben

Month	Barometer	Temperature: Mean Max.	Mean Min.	Mean	Extremes: Max.	Extremes: Min.	Relative Humidity	Vapour Pressure	Rain: Amount	Days	Heaviest Fall	Harmatons
1900	In.	°	°	°	°		p.c.	In.	In.	No.	In.	No.
une	30·08	87·9	72·2	80·8	92	71	84·4	·836	32·59	22	5·01	—
uly	30·10	82·9	75·9	77·9	90	70	85·8	·801	13·61	25	1·95	—
ugust	·09	81·1	72·0	77·1	86	70	88·2	·808	6·39	15	1·35	—
eptember	·07	84·9	73·4	80·8	92	70	85·7	·820	11·84	25	2·29	...
ctober	·04	88·4	73·9	82·3	91	70	85·6	·793	9·38	17	2·24	...
ovember	·00	88·3	72·6	82·8	91	71	83·9	·863	11·34	12	3·32	—
ecember	29·99	87·0	73·6	81·9	89	70	83·6	·812	1·32	1	1·32	14
1901												
anuary	29·99	88·0	71·7	83·4	90	68	78·8	·784	2·68	1	2·68	10
ebruary	·99	91·3	74·3	86·5	94	72	78·1	·834	0·69	5	0·23	
arch	·96	91·2	74·2	84·8	94	71	81·6	·863	7·70	8	2·25	--
pril	·98	90·9	73·6	85·5	93	71	75·8	·858	11·01	10	3·31	
ay	30·00	90·0	75·0	81·9	94	75	77·6	·814	10·95	19	2·97	--
ear	30·02	87·6	73·5	82·2	94	68	82·1	·824	119·50	150	5·01	24[1]

The mean temperature has been deduced from the formula $\left(\frac{7+1+9+9}{4}\right)$, the mean pressure and humidity from rmula $\left(\frac{7+1+9}{3}\right)$.

The observations in other respects are published as received.

The relative humidity at 7 a.m. was 91·0 p.c., at 1 p.m. it was 68·1 p.c., at 9 p.m. 87·2 p.c. The extremes noted \ 53 p.c. on January 27 and 95 p.c. in May.

Lauderdale, Mlanje. Lat. 16° 2' S., Long. 35° 30' E., 2,510 feet. Communicated by John W. M

Month	Mean Temperature: 6 A.M.	9 P.M.	Max.	Min.	Mean	Temp. Extremes: Highest	Lowest	Mean Temp. Wet Bulb: 6 A.M.	9 P.M.	Dew Point: 6 A.M.	9 P.M.	Vapour Pressure: 6 A.M.	9 P.M.	Relative Humidity: 6 A.M.	9 P.M.	Rain: Amount	Days	Highest Fall	Cl (0: 6 A.M.
1900	°	°	°	°	°	°	°	°	°	°	°	In.	In.	p.c.	p.c.	In.	No.	In.	
January	69·7	72·3	78·5	67·3	72·9	87·8	60·0	67·5	69·3	66·5	68·1	·650	·685	90	86	19·23	26	4·86	7·2
February	67·2	71·3	80·3	65·1	72·8	89·5	61·2	65·0	67·3	63·2	65·5	·592	·627	87	87	9·65	16	2·24	6·7
March	67·4	72·5	81·6	65·7	73·6	87·5	61·1	65·2	67·6	64·2	65·4	·599	·625	89	79	18·89	16	4·21	6·6
April	65·2	70·3	78·0	64·9	71·4	87·9	58·0	62·0	61·4	60·3	61·4	·523	·544	81	73	6·74	6	2·35	3·1
May	63·4	66·5	74·2	59·3	66·7	79·9	55·3	60·6	62·5	59·0	60·5	·500	·525	85	81	6·60	13	2·15	0·5
June	59·3	62·4	69·9	55·0	62·5	76·2	49·6	55·3	57·6	52·9	60·5	·397	·426	79	93	2·22	8	0·74	3·1
July	58·8	64·0	71·8	55·5	63·7	75·3	51·4	55·1	57·9	51·9	54·1	·386	·418	78	70	0·67	3	0·44	2·4
August	62·0	67·0	72·5	56·4	64·5	76·9	50·1	57·2	59·1	54·2	47·4	·420	·327	77	56	2·20	3	1·25	2·3
September	60·6	68·4	76·2	56·6	66·4	85·1	52·0	56·9	60·1	54·6	55·1	·426	·435	81	62	3·11	2	2·75	0·9
October	70·5	77·7	88·8	65·1	76·9	95·2	57·0	64·5	65·2	61·1	58·7	·537	·494	72	52	2·82	2	2·37	2·
November	70·7	74·5	83·7	65·6	74·7	91·3	60·0	66·3	67·8	64·3	64·7	·601	·611	80	71	8·94	9	5·44	3·
December	69·7	72·1	80·7	66·3	73·5	88·5	62·0	67·4	68·3	66·4	66·7	·647	·653	89	80	12·52	15	2·62	5·
Year 1900	64·5	69·9	78·0	61·9	69·9	95·2	49·6	62·0	64·0	59·9	60·7	·523	·531	82	74	93·59	119	5·44	3·
" 1899	63·8	67·8	76·5	61·6	69·0	99·8	49·2	49·2	67·3	58·7	60·3	·504	·529	84	77	128·14	182	8·56	4·
" 1898	63·8	68·9	78·0	62·8	70·4	95·0	51·2	51·2	68·6	59·6	61·2	·518	·547	87	77	158·87	207	9·67	4·
" 1897	—	—	81·6	62·0[1]	71·8	99·1	47·3	—	—	—	—	—	—	—	—	79·01	157	3·98	4·
" 1896	64·5[1]	68·8[1]	80·2	62·7	71·4	100·4	51·0	—	—	—	—	—	—	—	—	108·15	161	5·07	3
" 1895[1]	63·9	68·7	78·4	63·0	70·2	98·8	51·5	60·5	64·0	58·4	61·5	·394	·552	82	78	131·72	194	12·41	-
Mean, 1896–1900	—		78·9	62·2	70·5	97·9	49·7	—	—	—	—	—	—	—	—	113·55	165	6·55	4

[1] The mean temperature is assumed to be the mean of the max. and min. temperatures, and is about 1° too higl

Fort Johnston, Nyasaland. Lat.* 14° 28′ *S., Long.* 35° 15′ *E., Alt.* 1,590 *feet approx.

Month	Barometer (corrected for index error only)	Mean Temp.: Mean Max.	Mean Temp.: Mean Min.	Mean Temp.: Mean	Temp. Extremes: Highest	Temp. Extremes: Lowest	Dew Point	Vapour Pressure	Relative Humidity	Rain: Amount	Rain: Days	Rain: Heaviest Fall	Cloud (0–10) Mean	Sunshine
1898	In.	°	°	°	°	°	°	In.	P.c.	In.	No.	In.		Hrs.
January .	28·469	88·5	71·7	77·8	92·9	67·5	72·8	·806	83	7·54	23	1·14	6·7	—
February .	·489	86·7	69·2	75·7	91·9	66·8	69·7	·724	79	8·68	14	2·23	6·7	—
March .	·493	87·9	69·5	76·1	94·5	65·5	71·4	·769	84	6·89	18	1·77	6·6	—
April .	·559	84·6	65·9	73·2	94·7	60·0	67·4	·678	82	6·15	13	3·46	5·4	—
May .	·625	84·2	60·2	71·2	90·9	54·6	62·2	·560	75	0·11	1	0·11	3·1	—
June .	·723	78·4	57·7	66·7	89·7	51·4	57·0	·434	71	0·47	6	0·14	6·2	—
July .	·724	79·4	56·7	66·3	87·5	51·8	56·5	·456	71	0·02	2	0·01	5·4	—
August .	·707	81·3	56·2	67·2	90·0	49·4	55·2	·436	69	0·27	3	0·14	4·9	—
September .	·605	89·7	61·7	74·8	96·0	53·5	62·0	·556	65	0·04	1	0·04	3·8	—
October .	·531	96·9	65·4	81·1	105·9	60·0	67·2	·665	62	0·12	2	0·24	3·0	—
November .	·470	99·3	71·8	82·9	105·8	66·8	65·6	·708	62	2·06	7	0·81	6·7	—
December .	·485	·3·6	69·0	80·9	105·0	64·0	69·8	·726	69	9·36	17	1·72	7·3	—
Year 1898 .	·573	87·5	64·5	74·4	—	—	64·7	·627	73	42·01	107	2·23	5·5	—
1899														
January .	28·502	93·6	67·3	79·2	100·9	62·1	69·5	·715	71	1·80	8	0·72	4·7	247
February .	·448	88·7	67·6	79·5	100·2	64·3	70·7	·748	76	12·17	20	3·33	8·8	109
March .	·500	90·1	66·4	79·4	97·0	63·0	70·3	·741	79	6·46	13	1·40	4·8	246
April .	—	86·5	65·1	—	93·0	59·0	—	—	—	3·13	9	1·27	—	260
May .	—	82·8	60·9	—	85·0	49·0	—	—	—	0·38	6	0·10	—	202
June .	—	77·5	53·5	—	80·0	49·0	—	—	—	0·04	1	0·04	—	—
July .	—	81·8	56·1	—	86·0	54·0	—	—	—	0·00	0	—	—	—
1900														
January .	28·810	91·4	68·3	80·5	98·0	66·0	74·6	·858	81	11·37	20	2·34	5·7	—
February .	·856	91·4	67·1	77·9	98·0	63·5	72·9	·809	79	3·65	10	1·10	5·2	—
March .	·878	92·5	67·3	81·6	99·0	64·0	72·5	·798	75	2·57	11	0·69	4·0	—
April .	·922	91·3	65·1	80·7	95·0	62·0	71·8	·779	74	0·07	3	0·04	2·3	—
May .	·943	89·5	62·6	79·5	93·0	58·0	70·3	·743	73	0·17	2	0·15	3·0	—
June .	29·045	83·4	56·1	72·5	90·0	52·0	64·0	·598	71	0·01	1	0·01	3·0	—
October .	28·531	101·8	65·2	—	105·2	59·1	—	—	—	0·00	0	—	2·4	363
November .	·532	96·9	72·8	82·1	104·7	65·8	70·2	·741	64	2·86	10	0·65	3·8	269
December .	·497	93·9	68·0	80·2	99·1	61·8	71·5	·783	74	5·47	—	1·25	4·2	279

Fort Johnston.—The mean temperature is deduced from the formula $\frac{7+2+9+9}{4}$; the humidity from $\frac{7+2+9}{3}$. The barometer is corrected for index error but not reduced to 32° F.

Nkata Bay, Nyasa. Lat* 11° 37·5′ *S., Long.* 34° 18′ *E., Alt.* 1,645 *feet.

Month	Mean Temperature	Rain	Sunshine (estimated)
1900	°	In.	Hrs.
January .	75·4	11·50	165
February .	76·1	8·48	183
March .	74·6	16·31	210
April .	73·1	6·12	138
May .	72·0	4·53	257
June .	68·3	2·68	221
July .	67·8	0·78	272
August .	70·3	·33	294
September	72·9	·05	[308]
October .	77·8	·00	333
November.	81·8	·26	260
December.	80·2	11·93	248
Year 1900	74·2	62·87	2,889
„ 1899	74·1	60·30	—
„ 1898	72·8	90·72	2,834

Nkata Bay.—The mean temperature is deduced from the formula $\frac{(7+2+9+9)}{4}$. The totals and means are taken from Mr. J. McClounie's Summary Table.

Note to following Table.

Blantyre.—The above is taken from Mr. J. McClounie's Summary Table.

Blantyre, African Lakes Corporations Gardens.

Month	Mean Temp.: Max.	Mean Temp.: Min.	Rain
1898	°	°	In.
July .	6[illegible]·8	51·0	0·43
August .	6[illegible]·8	48·3	·18
September	7[illegible]·0	54·0	·09
October .	9[illegible]·9	62·0	·27
November.	8[illegible]·0	66·4	3·45
December.	8[illegible]·0	62·4	12·31
1899			
January .	82·0	62·4	4·61
February .	78·7	64·0	15·47
March .	78·6	61·0	9·45
April .	80·0	60·0	3·39
May .	77·1	53·6	1·61
June .	74·1	49·0	0·74
July .	79·0	48·0	·05
August .	—	—	·00
September	85·0	51·6	·00
October .	90·5	6[illegible]·7	·83
November.	84·4	62·4	5·17
December.	83·0	61·2	6·24
	81·5	63·0	1·63
	82·7	61·3	5·73
	86·2	61·0	5·10
	87·5	59·0	0·10
	81·5	55·0	·51
	85·3	51·0	·25
	82·0	48·0	·00
...t	—	—	·00
...nbe	88·2	51·7	·00
...er	92·6	61·0	·00
...ber.	—	—	9·80
...ber.	—		6·53
	—	—	39·65

Mombasa. 4° 4′ *S.*, 39° 42′ *E.*, 60 *feet.* *Observer: J. W. Tritton.*

Month	Pressure of Atmosphere 9 A.M.	Mean Temperatures					Temp. Extremes		Daily Range	Humidity, 9 A.M.			Rain			Cloudy days (Sundays excluded)
		Dry 9 A.M.	Wet 9 A.M.	Mean Max.	Mean Min.	Mean 9 A.M.	Highest	Lowest		Dew Point	Vapour Pressure	Relative Humidity	Amount	Days	Heaviest fall	
1900	In.	°	°	°	°	°	°	°	°	°	In.	P.c.	In.	No.	In.	No.
anuary .	29·831	83·0	80·8	87·0	82·5	84·7	88	80	4·5	79·8	1·016	93	4·09	7	1·05	17
'ebruary .	·846	84·9	82·8	87·5	82·7	85·1	90	70	4·8	82·2	1·096	94	2·23	5	1·05	11
larch .	·874	84·9	83·3	87·7	68·1[1]	77·9[1]	98	60[1]	8·6[1]	82·8	1·120	95	6·62	11	2·22	13
.pril .	·879	85·3	83·6	87·7	85·3	86·5	90	82	2·[illegible]	83·1	1·130	94	2·64	8	1·35	5
lay . .	·928	81·8	81·0	84·5	81·5	83·0	87	80	3·0	81·5	1·074	96	18·07	15	5·10	6
une. .	·946	79·7	78·1	82·4	80·3	81·3	84	79	2·1	77·5	0·942	95	2·53	10	0·60	10
uly . .	·963	78·9	77·2	81·9	80·1	81·0	86	79	1·8	76·6	·913	95	6·13	15	1·12	9
.ugust .	·959	79·2	77·5	81·4	80·9	81·1	83	79	0·5	76·9	·922	95	1·45	9	0·50	5
eptember .	·947	80·7	79·2	82·8	82·2	82·5	85	81	0·6	79·0	·988	98	2·34	8	1·05	2
ctober .	·870	81·8	80·2	83·4	82·9	83·2	85	81	0·5	79·7	1·011	95	6·22	9	1·83	5
'ovember	·817	83·2	81·6	85·1	83·5	84·3	88	81	1·6	81·1	1·059	95	5·44	9	1·65	6
ecember .	·786	83·5	81·4	85·4	84·2	84·8	87	82	1·2	80·8	1·047	94	3·86	8	1·07	10
'ear 1900	29·887	82·2	80·5	84·7	81·2	85·9	98	60	3·5	80·0	1·026	95	61·66	114	5·10	99
„ 1899	·911	81·7	79·4	85·9	78·6	82·3	90	73	7·3	78·5	·974	90	35·16	94	2·78	—
„ 1898	·889	81·4	78·5	84·5	76·2	80·3	87	69	8·4	75·9	·946	88	25·00[3]	39	2·50	—
„ 1897	·904	80·7	77·0	83·2	75·4	79·3	88	71	7·8	75·6	·886	85	52·56	42	5·50	—
„ 1896	·906	80·3	75·6	82·9	75·8	79·3	89	70	7·1	73·8	·832	81	65·24	94	4·31	—
'ean, 1896-1900.	29·899	81·5	78·1	84·2	77·4	81·4	90	71[2]	6·8	77·9[2]	·909[2]	86[2]	47·92	77	5·10	—

Mombasa.—All readings have been corrected for instrumental error, excepting those of the barometer, the records f which have, however, been reduced to 32° F. and to standard gravity in Lat. 45°.

[1] The readings of the minimum thermometer during March should be rejected. On 10 days the max. and min. emperature is stated to have been the same, and on 4 days the min. temp. is entered as having exceeded the max. emperature. It is probable that the wet bulb readings for several years past have been too high.

[2] Omitting the year 1900. [3] Partly estimated.

Shimoni (Wanga). 4° 38′ *S.*, 39° 21′ *E.*
Observers: M. G. Carvalho, E. H. L. Murray, and the late E. H. Russell.

Month	Atmospheric Pressure		Mean Temp. 9 A.M.		Humidity, 9 A.M.			Rain		
	9 A.M.	3 P.M.	Dry	Wet	Dew Point	Vapour Pressure	Relative Humidity	Amount	Days	Heaviest fall
1900	In.	In.	°	°	°	In.	P.c.	In.	No.	In.
January .	29·882	29·818	84·4	81·2	80·2	1·028	90	2·85	8	1·90
February .	·865	·813	84·5	82·5	81·9	1·087	94	·89	2	·70
March .	·909	·813	84·4	82·3	81·6	1·078	94	3·16	7	1·87
April .	·908	·811	81·4	79·5	78·9	·984	94	2·98	9	1·50
May . .	·914	·815	79·0	77·4	76·8	·921	95	21·15	25	4·92
June. .	·957	·860	76·3	74·9	74·4	·848	95	4·47	11	1·15
July . .	30·029	·966	76·6	75·1	74·5	·853	95	5·06	21	1·30
August .	·041	·970	75·9	74·8	74·5	·853	97	2·82	16	·50
September	·010	·969	76·5	76·4	76·0	·897	99	2·45	8	1·45
October .	29·979	·920	79·0	77·8	77·4	·938	96	3·69	8	·75
November	·906	·945	80·9	79·8	79·4	1·003	94	8·66	12	3·00
December.	·878	·835	81·1	80·0	79·6	1·010	98	1·58	13	·39
Year 1900	29·940	29·878	80·0	78·5	77·9	·958	95	59·76	120	4·92
„ 1899	·943	·879	76·6	77·7	77·0	·927	92	52·51	91	4·60
„ 1898	·901	—	80·7	79·1	78·5	·974	93	27·30	85	2·80
„ 1897	·788	—	81·0	79·1	79·3	·977	92	56·75	109	4·60
„ 1896	·805	—	80·1	76·5	75·2	·874	85	56·57	111	5·25
Mean, 1896-1900.	29·875	—	79·7	78·2	77·6	·942	91	46·56	103	5·25

Shimoni.—All readings have been corrected for instrumental error (see Report for 1898, p. 4). The dry bulb readings are those of the thermometer attached to a barometer.

The barometer readings have been reduced to 32° F. and Lat. 45°, but not to sea-level.

Lamu. 2° *S.*, *Long.* 40° *E.*
Observers: A. S. Rogers, Wallace Blake, J. J. Anderson.

Month	Mean Temp. 9 A.M.		Humidity 9 A.M.		
	Dry	Wet	Dew Point	Vapour Pressure	Relative Humidity
1900	°	°	°	In.	P.c.
January .	84·5	80·5	79·2	·995	88
February .	84·7	81·7	80·7	1·047	
March .	85·0	80·8	79·5	1·003	
April .	83·0	81·5	81·0	1·057	
May . .	83·6	80·8	79·9	1·019	
June .	81·4	78·6	77·7	0·946	
July. .	79·5	76·1	74·8	·862	89
August .	78·9	76·2	75·3	·873	90
September	79·1	77·1	76·4	·907	94
October .	82·3	80·3	79·3	1·000	91
November	84·0	82·5	82·4	1·106	96
December.	84·5	82·4	81·7	1·082	
Year 1900	82·5	79·9	79·0	·991	91
„ 1899	82·2	79·3	78·4	·970	88
„ 1898	82·0	78·2	76·8	·922	84
„ 1897	81·6	78·7	77·6	·951	88
„ 1896	82·0	77·4	75·7	·886	81
Mean, 1896-1900.	82·1	78·7	77·5	·944	

Lamu.—The rainfall for 1899 is partly estimated. No rainfall observations have been made since September of that year.

The rainfall was 41·29 in. in 1896; 32·28 in. in 1897; 12·39 in. in 1898; about 14 in. in 1899, and the mean (1896–1900) 28 in.

The heaviest fall (8·25 in.) occurred in April 1897.

Takaungu. Lat. 3° 41′ S., Long. 39° 52′ E. Observers: C. F. Braganza and G. H. L. Murray.

Month	Rain: Amount	Rain: Days	Rain: Heaviest fall in 24 hours
1900	In.	No.	In.
January	0·71	2	0·47
February	1·83	5	0·43
March	5·23	4	4·16
April	3·65	7	2·45
May	26·15	22	5·43
June	2·05	9	0·68
July	3·79	22	0·48
August	1·12	18	0·27
September	2·30	14	0·60
October	6·40	13	2·72
November	3·72	10	0·79
December	1·11	6	0·40
1900	58·09	124	5·43
1899	33·15	116	2·08
1898	24·00	71	1·75
1897	54·40	104	5·13
1896	47·80	79	3·27
1895	35·71	68	3·30
Mean, 1896-1900	43·49	99	3·51

Kisimayu. Lat. 0° 22′ S., Long. 43° 33′ E. Observers: R. G. Farrant, Wallace Blake, and R. W. Humphrey.

Months	Atmospheric Pressure 9 A.M.	Mean Temp. 9 A.M.	Rain: Amount	Rain: Days	Rain: Heaviest fall in 24 hours
1900	In.	°	In.	No.	In.
January	29·920	83·3	—	—	—
February	·876	83·5	—	—	—
March	·992	84·9	0·48	1	0·48
April	30·338	85·6	·03	1	·03
May	·135	84·1	3·67	6	1·83
June	29·957	80·1	3·17	8	1·50
July	·914	79·0	1·81	8	0·61
August	·959	79·4	0·10	2	0·08
September	·997	80·0	·04	1	·04
October	·936	80·1	·00	0	—
November	·810	82·7	1·75	4	1·10
December	·808	81·8	1·82	0	0·92
Year 1900	29·972	82·0	12·87	31	1·83
„ 1899	·925	81·1	12·40	37	4·12
„ 1898	29·885	80·8	10·91	30	3·44

The readings have been corrected for instrumental error.

The barometrical readings have been reduced to standard temperature of 32° and standard gravity in lat. 45°, but not to sea-level.

Nairobi. Lat. 1° 2′ S., 36° 57′ E., 5,450 ft. Observers: W. D. Spiers, F. Gilkison, Louis S... [illegible].

Month	Rain: Amount	Rain: Days	Rain: Heaviest fall in 24 hours
1899	In.	No.	In.
October	4·62	5	3·46
November	2·30	10	0·75
December	2·34	4	1·56
1900			
August	0·00	0	—
September	0·17	1	0·17
October	0·47	8	·18
November	6·48	15	·79
December	5·26	13	1·79

Kitui. Lat. 1° 50′ S., Long. 38° E. Observer: S. L. Hinde.

Month	Temperature: Mean Max.	Mean Min.	Extremes: Max.	Extremes: Min.	Rain: Amount	Days	Heaviest fall
1900	°	°	°	°	In.	No.	In.
July	71·3	57·1	77	52	0·23	5	0·12
September	76·7	60·0	80	58	0·18	1	0·18
October	74·6	62·3	78	60	13·81	7	4·40
November	80·5	62·0	—	60	12·58	12	2·80
December	75·6	63·3	78	61	14·55	14	3·20

Malindi. Lat. 3° 13′ S., Long. 40° 7′ E. Observer: James Weaver.

Month	Mean Temp. 9 A.M.: Dry	Wet	Humidity, 9 A.M.: Dew Point	Vapour Pressure	Relative Humidity	Rain: Amount	Days	Heaviest Fall
1900	°	°	°	In.	P.c.	In.	No.	In.
January	84·4	78·3	76·1	·899	82	0·87	6	0·35
February	85·2	80·6	79·1	·992	86	·33	2	·18
March	85·5	80·3	78·6	·975	84	·56	4	·30
April	84·7	80·3	78·8	·987	86	1·96	6	·51
May	82·4	79·2	78·1	·960	90	17·08	14	5·25
June	79·7	76·5	75·4	·876	90	1·84	4	0·73
July	78·4	74·4	72·8	·805	87	2·77	6	·66
August	79·3	74·7	72·9	·808	86	1·72	5	·38
September	79·7	75·2	73·9	·831	89	1·48	5	·67
October	80·9	75·9	74·0	·838	85	2·30	7	·60
November	80·3	77·4	76·3	·906	91	3·68	8	1·32
December	81·5	77·7	76·4	·907	88	2·47	7	1·43
Year 1900	81·8	77·5	76·0	·898	87	37·05	74	5·25
„ 1899	81·4	75·9	73·8	·833	78	33·38	102	5·30
„ 1898	81·7	77·1	75·4	·882	81	14·44	53	1·65
„ 1897	—	—	—	—	—	58·00[1]	91	4·85
„ 1896	81·1	78·0	76·9	·929	87	53·60	89	4·36
Mean 1896-1900	81·5	77·1	75·5	·885	83	39·29	82	4·28

[1] Partly estimated.

Fort Smith, Kikuyu. Lat. 1° 14′ N., Long. 36° 44′ E. Alt. 6,400 feet. Observer: Francis G. Hall.

Month	Mean Temp. 9 A.M.: Wet	Dry	Humidity 9 A.M.: Dew Point	Vapour pressure	Relative density	Rain: Amount	Days	Heaviest fall in 24 hours
1899	°	°	°	In.	P.c.	In.	No.	In.
January	59·9	65·5	63·2	·575	92	0·29	1	·29
February	61·0	68·0	65·4	·624	92	0·81	2	·60
March	60·1	66·5	63·8	·590	91	2·54	5	1·94
April	62·0	65·0	63·8	·590	96	5·11	15	2·41
May	60·0	62·8	61·8	·551	97	4·79	16	1·44
June	55·3	57·6	56·5	·457	96	·07	2	·05
July	54·0	58·6	56·2	·452	92	1·09	12	·23
August	54·6	57·3	55·9	·466	98	·67	9	·17
September	56·8	60·4	54·8	·429	92	·01	1	·01

During a thunder and hail storm at 3.20 P.M. on May 18 the thermometer dropped 13 degrees in half an hour.

Machako's, Lat. 1° 31′ *S., Long.* 37° 18′ *E.,* 5,400 *feet.* *Observer: W. Maclellan Wilson.*

Month	Aneroid, 9 A.M.	Temperature 9 A.M.	Mean Max.	Mean Min.	Extremes Max.	Extremes Min.	Humidity 9 A.M. Dew Point	Vapour Pressure	Relative Humidity	Rain Amount	Days	Heaviest fall in	Cloud (0–10) 9 A.M.	Mean Force of Wind (0–10)
1900	In.	°	°	°	°	°	°	In.	P.c.	In.	No.	In.		
January	24·74	66·1	73·7	56·4	79·2	54·7	58·7	·495	77	8·17	17	2·18	2·5	1·7
February	·74	67·9	75·1	57·9	78·7	52·5	58·3	·487	71	8·10	15	1·74	5·0	1·2
March	·74	66·6	75·1	59·0	78·5	54·6	60·1	·521	80	10·15	21	2·41	7·5	1·2
April	·74	65·8	71·0	59·2	78·3	56·1	58·7	·497	79	5·13	16	1·93	6·8	1·1
May	·85	63·9	73·0	56·9	75·8	48·0	57·9	·481	81	5·89	13	1·60	6·9	0·9
June	·86	61·3	71·0	54·8	73·6	43·5	56·2	·552	80	0·07	2	0·06	7·8	1·1
July	·86	59·6	68·1	52·7	72·6	47·9	53·6	·412	80	0·35	7	0·09	8·4	1·5
August	·81	60·6	70·7	53·1	76·8	42·9	53·7	·413	79	0·08	6	0·02	7·6	1·0
September	·80	62·5	74·3	54·5	78·3	48·0	53·8	·415	73	·00	0	—	7·3	1·2
October	·75	65·6	77·2	57·3	82·7	53·0	55·2	·437	71	3·40	8	1·53	4·9	1·4
November	·71	66·2	72·8	58·1	76·8	53·2	58·8	·496	78	8·64	21	1·04	6·5	1·6
December	·70	65·4	71·4	58·7	74·6	56·4	59·0	·501	81	8·04	28	0·95	6·6	1·6
Year 1900	24·775	64·3	73·0	56·7	82·7	42·9	56·9	·475	77·5	58·32	154	2·41	6·5	1·3

Machako's.—The force of wind is estimated according to a scale adopted by the observer, thus: 0 (actually 'calm' and included in the last column of our summary; 1, calm (velocity up to 0 5 mile); 2, light (velocity 6–15 m.); 3, moderate (velocity 16–25 m.); 4, fresh (velocity 26–30 m.); 5, strong (velocity 31–40 m.); 6, gale (velocity over 40 m.). The most frequent winds come from the S.E., but the strongest blow from the N. and N.N.E. (force 2·7 and 2·0).

Machako's—continued.

Frequency, Direction and Total Force (0–6) of Winds, at 9 A.M.

Month, 9 A.M.	N. No.	N. Force	N.N.E. No.	N.N.E. Force	N.E. No.	N.E. Force	E.N.E. No.	E.N.E. Force	E. No.	E. Force	E.S.E. No.	E.S.E. Force	S.E. No.	S.E. Force	S.S.E. No.	S.S.E. Force	S. No.	S. Force	S.S.W. No.	S.S.W. Force	S.W. No.	S.W. Force	W.S.W. No.	W.S.W. Force	W. No.	W. Force	W.N.W. No.	W.N.W. Force	N.W. No.	N.W. Force	N.N.W. No.	N.N.W. Force	Calm No.
1900																																	
January	1	1	1	1	4	8	4	8	6	12	1	1	6	9	4	7	1	2	1	1	—	—	—	—	—	—	—	—	—	—	—	—	2
February	2	3	1	1	4	8	1	1	5	7	—	—	4	6	3	5	—	—	—	—	1	1	1	1	1	1	—	—	—	—	—	—	6
March	—	—	1	1	5	8	—	—	3	6	2	2	7	10	3	7	—	—	1	1	—	—	—	—	1	1	—	—	1	1	—	—	7
April	—	—	—	—	—	—	—	—	2	2	4	5	8	12	5	7	2	5	—	—	1	1	1	1	—	—	—	—	—	—	—	—	6
May	—	—	—	—	—	—	—	—	4	7	2	2	9	10	1	1	—	—	—	—	3	4	2	2	—	—	—	—	—	—	1	1	9
June	—	—	—	—	—	—	—	—	4	6	4	6	3	5	—	—	1	2	—	—	8	13	—	—	—	—	—	—	—	—	—	—	[illegible]
July	—	—	—	—	—	—	—	—	5	14	8	14	4	8	1	4	1	1	—	—	1	3	1	2	—	—	—	—	—	—	—	—	[illegible]
August	—	—	—	—	—	—	—	—	5	9	4	8	7	14	—	—	1	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	[illegible]
September	—	—	—	—	—	—	—	—	5	12	8	12	4	10	1	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	[illegible]
October	—	—	—	—	1	1	1	4	5	10	4	4	4	8	1	4	2	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	[illegible]
November	1	5	2	8	2	6	3	5	1	3	2	3	5	11	4	8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	[illegible]
December	2	7	8	19	2	4	2	3	3	6	1	2	2	3	1	2	1	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	[illegible]
Year 1900	6	16	13	30	18	36	11	21	48	94	40	59	61	106	21	48	9	16	3	3	14	22	5	6	2	2	—	—	1	1	1	1	10[illegible]

Kikuyu, about Lat. 1° 11′ *S., Long.* 36° 42′ *E.,* 6,400 *ft.*

Month	Mean Temperature Max.	Mean Temperature Min.	Rain Amount	Rain Days	Rain Heaviest Fall
1900	°	°	In.	No.	In.
January	—	—	5·25	8	1·54
February	—	—	9·21	14	2·80
March	—	—	5·66	14	1·46
April	—	—	5·18	21	0·74
May	—	—	7·85	21	2·23
June	—	—	2·22	4	1·35
October	78·4	61·9	6·04	15	2·00
November	77·4	61·0	6·67	20	1·45
December	75·7	59·4	4·68	22	1·43

The observations up to June were made at the Station of the East African Scottish Mission (by Rev. T. Watson); the remainder at Fort Smith, 2¼ miles [illegible]

Natete, near Mengo (Buganda). Lat. 0° 20′ *N., Long.* 32° 36′ *E.,* 4,000 [illegible]
Observer: A. M. Mackay, Church Missionary Society.

Month	Rainfall. Amount in Inches 1879	1881	1882	1883	1884	1885	1886	Rainfall. No. of Days 1879	1881	1882	1883	1884	1885	1886	Mean Max. Tem. F.
															°
Jan.	5·60	3·36	1·58	1·50	0·52	1·19	2·05	11	5	6	6	5	8	4	87·2
Feb.	3·65	4·84	4·96	2·60	3·30	5·04	3·83	12	9	12	5	5	6	5	86·0
Mar.	5·27	6·58	2·11	2·93	3·02	*6·62*	3·85	11	15	9	6	6	14	7	87·5
April	5·67	*13·60*	*8·41*	*7·03*	4·30	5·73	*8·90*	13	12	9	6	4	5	9	81·4
May	*8·00*	4·26	3·87	4·32	2·45	5·17	8·69	15	11	9	9	3	6	8	79·3
June	2·05	2·58	1·88	2·92	3·92	5·16	2·51	3	8	6	6	9	6	7	78·2
July	0·35	2·63	2·88	*5·39*	3·58	5·21	—	1	5	8	10	5	5	—	79·6
Aug.	1·14	3·50	3·10	4·75	1·40	3·46	—	9	8	4	9	6	5	—	82·1
Sept.	*5·53*	3·04	4·67	2·78	4·30	3·07	—	13	8	8	10	10	3	—	86·7
Oct.	3·48	3·54	*7·60*	2·27	*9·24*	*5·32*	—	11	11	12	8	9	5	—	88·[illegible]
Nov.	3·31	*4·68*	2·81	3·93	4·34	4·28	—	11	12	9	12	11	11	—	84·4
Dec.	1·52	2·31	1·04	0·80	0·29	2·04	—	6	5	5	5	2	7	—	84·[illegible]
Year	45·57	54·95	44·91	44·22	40·66	52·59	—	114	109	97	92	75	76	—	83·[illegible]

The above are taken from the journals of the late A. M. Mackay, brought to Engl[illegible] Dr. Junker. The temperatures are the means of observations made between Janua[illegible] and June 1886. They have been corrected for supposed index-errors, but the mean m[illegible] appear to be still very much too high. In November 1885 the thermometer was rem[illegible] the north side of the house, and the mean maximum at once fell from 91·2° in October [illegible] in November 1885. The mean for the months November to June, before the remov[illegible] 84·8° after the removal only 83·0°. According to observations made by Rev. E. M. [illegible] [illegible] 82·1° (see Third Report).

Victoria Nyanza Lake Levels and Rainfall, in Decades.
Observers: F. Pordage, F. A. Knowles, H. Galt, S. Spire, W. R. Walker, and others.

Decades		Ntebe, 1899 Lake Level	Fort Thruston, 1899 Lake Level	Ntebe (P. Alice), 1900 Lake Level	Ntebe (P. Alice), 1900 Rainfall Amt.	Ntebe (P. Alice), 1900 Rainfall Days	Ntebe (P. Alice), 1900 Rainfall Heaviest Fall	Fort Thruston (Lubwas) Lake Level, 1900	Kisumu, on Kavirondo or Ngowe Bay. Lake Level, 1900
		In.	In.	In.	In.		No.	In.	In.
January,	I.	+3·00	−0·76	−6·68	1·14	1	0·75	..	− 5·30
"	II.	2·62	−1·03	−6·38	1·12	4	0·62	—	− 5·85
"	III.	2·67	−1·31	−6·12	0·00	..	—	—	− 6·45
February,	I.	3·67	−2·81	−5·88	1·37	6	0·63	—	− 7·80
"	II.	3·17	−2·56	−5·38	2·63	3	2·50	—	− 8·20
"	III.	2·66	−1·85	−5·03	0·23	3	0·07	...	− 4·67
March,	I.	3·04	−2·36	−5·33	0·02	1	0·02	--	− 7·80
"	II.	2·72	−2·98	−5·03	2·77	5	1·16		− 8·20
"	III.	2·47	−3·55	−4·53	3·31	8	1·39	.	− 4·67
April,	I.	1·72	−3·73	−5·53	1·81	5	0·85	..	− 5·10
"	II.	1·82	−3·68	−5·53	6·87	8	1·96	--	− 5·50
"	III.	3·97	−2·18	−5·53	4·86	7	1·50	..	− 3·90
May,	I.	3·64	−2·48	−4·28	1·01	3	0·93	—	+ 0·75
"	II.	4·54	+0·32	−5·03	0·47	1	0·27	—	− 2·35
"	III.	4·22	+3·22	−4·58	1·22	6	0·62	—	− 2·94
June,	I.	4·89	+2·17	−4·28	4·69	4	2·82	−19·18	− 2·50
"	II.	4·42	−0·28	−3·63	1·69	6	0·80	−18·98	− 1·50
"	III.	4·65	−1·13	−3·13	0·03	2	0·02	−18·53	− 3·75
July,	I.	4·97	−3·08	−3·03	0·00	—	—	−18·83	− 5·50
"	II.	4·95	−2·73	−2·53	0·15	3	0·08	−18·88	− 6·90
"	III.	3·61	−2·93	−2·15	0·28	1	0·28	−18·80	− 7·76
August,	I.	2·17	−8·23	−2·78	1·00	4	0·35	−18·78	− 6·97
"	II.	+0·32	−12·18	−3·23	1·25	1	1·25	−18·73	− 7·90
"	III.	−2·30	−13·49	−4·12	0·65	1	0·65	−19·08	−12·57
September,	I.	−3·55	−16·38	−5·83	0·22	1	0·22	−20·43	−10·10
"	II.	−4·68	−17·08	−7·33	3·10	4	1·25	−21·13	−10·65
"	III.	−6·58	−18·98	−10·23	0·11	4	0·04	−23·43	− 6·30
October,	I.	−6·33	−19·93	−13·33	0·15	4	0·05	−25·28	−15·05
"	II.	−7·13	−21·78	−15·93	0·35	3	0·27	−26·78	−16·20
"	III.	−7·76	−22·13	−17·21	1·03	4	0·8	−29·21	−16·75
November,	I.	−8·30	.	−18·08	1·53	5	1·15	−30·18	−17·60
"	II.	−8·88	...	−18·73	1·29	3	0·76	−30·13	−16·45
"	III.	−9·73	...	−19·53	3·17	8	1·36	−30·63	−16·90
December,	I.	−9·53	—	−18·98	4·24	4	1·61	−28·13	−15·97
"	II.	−8·93	—	−18·08	4·38	5	2·10	−27·68	−14·60
"	III.	−6·48		−16·53	3·89	4	1·67	−23·03	−11·48

Month	Ntebe. Rain, 190 Amount	Days	Heaviest Fall
	In.	No.	In.
Jan.	2·26	8	0·7
Feb.	4·23	12	2·5
Mar.	6·10	14	1·3
Apr.	13·54	20	1·9
May	2·70	13	0·9
Jun.	5·81	12	2·8
July	0·43	4	0·2
Aug.	2·90	6	1·2
Sept.	3·43	9	1·5
Oct.	1·53	11	0·7
Nov.	5·99	16	1·3
Dec.	12·51	13	2·1
Year	61·43	138	2·8

There can be no doub that the lake level is pri marily influenced by th rainfall. At Ntebe th level rose in the cours of 1898 (which was year of abundant rains) but in the course of 189 it fell slightly below th level of 1896, and in 190 it fell a further 7·6 inches. As that yea (1900) was one of fairl abundant rains along th Buganda shore (61 inche fell at Ntebe) we ar bound to assume that i is not local rains whicl appreciably affect th level of the lake, but th precipitation throughou its vast drainage are Thus an abundant rain fall along the Bugand shore would be neutral ised by a deficiency i the rainfall in the south Since the beginning o the present year (1901 the lake has risen rapidly, and by June 1 its level stood 24 inches above the mean level of 1896. The relations betwee local rainfall and lake level are illustrated by the following facts :—

At Ntebe, between March 20-24, 1900, 3·7 inches of rain fell, and in the course of April 13·54 inches, yet the level of th lake remained unaffected, the heavy local rains being balanced by the outflow and the loss by evaporation, or deficienc of rain elsewhere. Yet in the course of May the lake rose slowly, but steadily, although very little rain was registere locally. Again, between December 3-5 4·21 inches of rain fell, while the lake only rose half an inch. More remarkable still on September 12 1·25 inches of rain fell, yet the lake level actually fell half an inch. The other stations afford similar instance

The *winds* exercise a decided influence upon the level of the lake. There are regular land and lake breezes, an Mr. Macallister remarks that a strong S.W. breeze will cause a rise in the level of the lake to an extent of fro 1 to 3 inches. At Fort Thruston, on November 13, a severe storm caused the lake to rise 3 inches. The influence of th wind could be eliminated by making at least three observations daily, and which would be preferable, by establishing self-registering gauge. Further fluctuations of the lake may be produced by differences of barometric pressure.

The difference between the highest and lowest level at Ntebe amounted to 19·0 inches in 1896, 16·5 inches in 1899, an 17·50 inches in 1900. The extreme range, as far as our observations extend, has been 43·5 inches; but if the level, in 1881 exceeded that of 1898 to the extent of 8 feet, as asserted by the French missionaries in Buganda, its amount cannot be les than 10 feet.

All observations made at Ntebe and Fort Thruston (Lubwa's) are referred to the mean lake level at those stations i 1896. On October 1898 Mr. C. W. Fowler, Superintendent of Marine, claims to have adjusted all gauges to Port Victoria (wher observations ceased to be made at the end of July 1899). I fail to see how this can have been done unless the three station were joined by a line of spirit levelling. On comparing the observations made between October 1898 and February 1899 as recorded, I find that, assuming the level at Port Victoria to be −0·00, the level at Ntebe exceeded that datum level t the extent of 1·98 inches, whilst that at Fort Thruston fell short of it to the extent of 1·89 inches. Such differences in th level may exist, though I fail to see how they can have been ascertained. From all observations recorded since October 189 30·53 inches have been deducted in order to reduce them approximately to the mean lake level of 1896. In the case of Kisum however, only 30·3 inches have been deducted.

Victoria Nyanza Lake Levels and Rainfall, in Decades—cont.

In order to elucidate the interesting problems connected with the physical geography of the Victoria Nyanza, would be necessary to instal rain-gauges throughout its drainage basin, and to establish at least four gauges measuring the level of the lake, and to connect these gauges by lines of spirit level; a consummation most devou to be wished, though not likely to be realised for a considerable time to come. The observations should, as a matt of course, embrace all atmospheric phenomena, and more especially atmospheric pressure.

Victoria Nyanza.—Lake Levels and Rainfall, Monthly Means.

Month	Ntebe (P. Alice)			Fort Thruston (Lubwa's)			Port Victoria (January to July 1899), Kisumu, on Kavirondo or Ngowe Bay (September 1899 to December 1900)					
	Mean Level	Extremes		Mean Level	Extremes		Mean Level	Extremes		Rain		
		Highest	Lowest		Highest	Lowest		Highest	Lowest	Amt.	Days	Hi e F
1899	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	No.	I
January	+ 2·76	+ 3·97	+ 2·47	− 1·04	+ 0·97	− 1·53	+ 0·73	+ 2·47	− 1·03	—	3	-
February	+ 3·20	+ 6·47	+ 1·47	− 2·42	− 0·53	− 3·53	− 0·63	+ 0·97	− 2·53	—	9	-
March	+ 2·64	+ 3·97	+ 0·72	− 2·95	− 1·53	− 4·03	− 1·79	+ 0·97	− 3·53	1·03	8	0·
April	+ 2·50	+ 5·47	+ 0·97	− 3·30	+ 0·47	− 4·03	+ 1·56	+ 1·47	− 5·03	3·38	18	0
May	+ 4·14	+ 6·47	+ 2·97	+ 0·10	+ 4·72	− 3·03	+ 2·21	+ 6·47	− 2·53	4·85	19	1·
June	+ *4·65*	+ 5·97	+ 3·47	+ *0·78*	+ 3·47	− 2·53	+ *2·30*	+ 5·47	− 0·53	2·55	10	0·
July	+ 3·83	+ 5·97	+ 1·47	− 2·92	− 1·53	− 5·53	− 3·96	+ 0·47	− 8·53	0·10	4	0·
August	− 0·02	+ 2·97	− 3·03	−11·16	− 3·03	−14·53	—	—	—	—	—	-
September	− 4·94	− 3·03	− 8·03	−16·48	−15·53	−19·53	− 3·12	+ 3·20	− 7·30	2·68	13	0·
October	− 7·09	− 6·03	− 8·03	−21·42	−19·53	−23·53	− 7·20	− 4·30	−10·30	2·91	12	1·
November	− *8·98*	− 8·03	−10·03	—	—	—	− 8·13	− 4·30	−11·30	4·64	11	1·
December	− 8·61	− 7·03	− 9·53	—	—	—	− 6·17	+ 2·20	−11·80	5·04	14	1·
Year	− 0·51	+ 6·47	−10·03	—	—	—	—	—	—	—	—	-
1900												
January	− 6·38	− 6·03	− 7·03	−21·5	—	—	− 5·85	− 1·30	− 8·30	5·18	17	1·
February	− 5·46	− 5·03	− 6·03	−21·5	—	—	− 5·94	− 2·30	−10·30	6·45	14	2·
March	− 4·95	− 4·53	− 3·53	−21·5	—	—	− 7·14	+ 1·70	−12·30	4·64	11	1·
April	− 5·53	− 5·53	− 5·53	−20·5	—	—	− 4·83	− 1·80	− 7·30	5·04	14	1
May	− 4·95	− 4·53	− 5·53	−19·5	—	—	− 1·62	+ 2·70	− 5·30	1·88	10	1·
June	− 3·78	− 3·03	− 4·53	−18·90	−18·03	−20·53	− 2·58	+ 0·70	− 6·30	2·86	11	0
July	− 2·66	− 2·03	− 3·03	−*18·84*	−18·53	−19·03	− 6·75	− 3·30	−12·30	1·56	10	1·
August	− *2·37*	− 2·53	− 4·53	−18·87	−18·53	−19·03	− 8·91	− 6·30	−12·30	2·70	10	0·
September	− 7·86	− 5·03	−11·53	−21·66	−19·53	−24·53	− 8·98	− 4·30	−12·30	3·66	12	1·
October	−15·53	−12·53	−17·53	−26·16	−24·53	−30·03	−16·03	−10·30	−19·30	2·80	5	2·
November	−*18·75*	−17·53	−19·53	−*30·31*	−29·30	−32·03	−16·98	−12·30	−24·30	6·27	10	1·
December	−17·82	−15·53	−19·53	−26·27	−21·53	−30·53	−12·78	− 5·80	−18·30	6·23	10	1·
Year	− 8·13	− 2·03	−19·53	—	−18·03	−32·03	− 8·20	+ 2·70	−21·30	49·36	134	2·

1899.—At *Ntebe* the lake attained its highest level on June 8. It stood lowest from November 25-28. T difference between the highest and lowest levels amounted to 16 inches.

1900.—At *Ntebe* the lake reached its highest level on July 21 and maintained it up to July 28. It stood at lowest from November 21 to December 2. The difference between the highest and lowest levels amounted 17·5 inches. During the whole of April the lake steadily maintained its level of 5·53 inches below the le of 1896.

At *Fort Thruston* the lake level was lowest on November 12, and highest on June 22, the difference amounti to 14 inches. At *Kisumu* it was lowest on November 3, highest on May 10, the range having been 27 inches, amount accounted for by the position of the gauge in shallow water at the bottom of a bay and high winds.

1901.—At *Ntebe* the lake on June 1 stood 23·43 inches above the level of 1896; at *Kisumu* on May 7 it stood o 15·16 inches above that level, as assumed by us; and on June 28 14·0 inches.

The bench mark cut on the Camp Tree at the head of Port Florence in 1898 by Commander B. Whitehouse, R. is 19 feet 11 inches above the zero on the Lake Gauge.

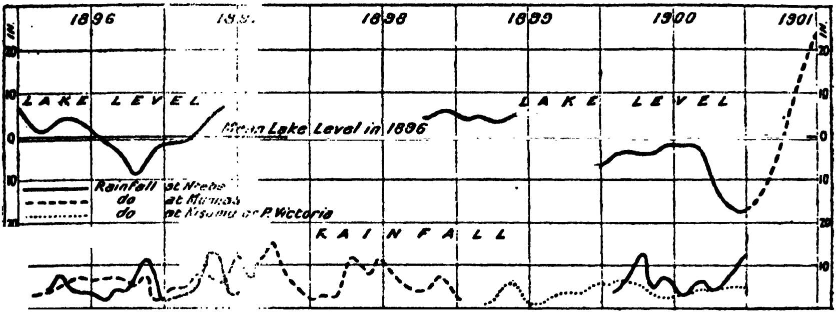


Diagram illustrating the Fluctuations in the Level of the Victoria Nyanza, at Ntebe, in 1896–1901, compared with the Rainfall.

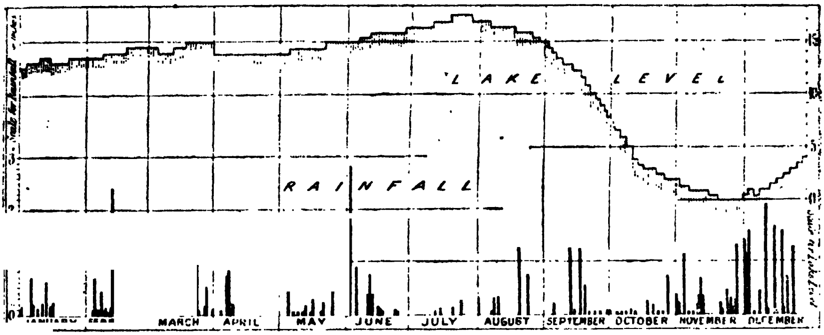


Diagram illustrating the Fluctuations in the Level of the Victoria Nyanza, at Ntebe, in 1900, compared with the Rainfall.

Annual Rainfall in British Africa, in Inches.

	British East Africa : Coast						British East Africa : Inland				Nyasaland		
Y	Ki m!	lindi	Lamu	T aunga	basa[1]	Chuyu (Wanga)	Kibwezi	Machal	Fort Smi (Kikuyu	Mumia (Kavir	Blaı re	Dun aven	Laud rdale
1890			29·0	—	34·7	—	—			—	—	—	—
1891		42·0	—	—	*46·6*	—				—	—	—	—
1892	—	*30·1*	—	32·1	*26·4*	—	—	—	—	—	—	89·8	—
1893	—	*50·8*	44·5	*40·7*	*64·2*	*66·3*	—	—	53·0	—	—	90·1	—
1894	*13·7*	*28·9*	*21·1*	38·0	38·0	42·0	26·7	42·0	48·1	—	—	95·4	104·4
1895	—	34·9	—	*35·7*	*34·3*	*38·5*	33·1	—	*65·0*	—	—	*106·0*	*131·7*
1896	19·5	53·6	*41·3*	47·8	*65·2*	56·6	21·7	*25·9*	*29·5*	58·8	52·0	95·4	108·1
1897	*19·9*	*58·0*	32·3	*54·4*	52·6	*56·7*	*21·5*	*31·7*	36·3	*93·5*	—	*64·8*	*79·0*
1898	*10·9*	*14·4*	*12·4*	*24·0*	*25·0*	27·3	—	24·3	36·2	69·10	60·0	*96·7*	*158·9*
1899	12·4	33·4	22·0	33·1	35·2	52·5	—	*21·8*	—	—	47·5	88·7	128·1
1900	12·9	37·0	—	*58·1*	*61·7*	*59·8*	—	*58·3*	—	50·0	39·6	*60·0*	*93·6*

[1] At Frere Town (opposite Mombasa) 41·9 in. fell in 1876; 91·1 in. in 1877; 51·3 in. in 1878; 45·6 in. 1879; and 44·7 in. in 1880.

This summary shows that the annual rainfall varies exceedingly from year to year. At Mombasa, in the course of 11 years, it varied from 25 to 64 inches; at Machako's, during 6 years, from 22 to 58 inches. The years 1877, 1893, 1896, and 1897 and 1900 would appear to have been remarkable for an excessive rainfall along the coast of British East Africa; whilst in Nyasaland the years 1895 and 1898 were marked by heavy rains, whilst on the East Coast these years were exceptionally dry. It seems thus perfectly clear that there is no relation between the rainfall and the frequency of sun-spots.

Erratum in Report for 1897.

P. 9, second column, line 7 from bottom: *instead* of 8·4 in. *read* 9·1 in.

Errata in Report for 1900.

P. 2, second column, line 18: *instead* of 29·756 *read* 29·839.
P. 6, first column, line 16: *instead* of 1898 *read* 1896.

The Survey of British Protectorates.—Report of the Committee, consisting of Sir T. H. HOLDICH (*Chairman*), Col. G. E. CHURCH, Mr. E. G. RAVENSTEIN, *and* Mr. H. N. DICKSON (*Secretary*), *appointed to draw up a Scheme for the Survey of British Protectorates.*

YOUR Committee are of opinion that a representation should be submitted to His Majesty's Government in support of an organised scheme for surveying British Protectorates in Africa, and that it would be advantageous to secure the co-operation of the Royal Geographical Society, and of other bodies unconnected with Government who may be specially interested in the matter, in bringing forward their proposals. At present, various surveys have been commenced in different parts of Africa under local administrations, which are unconnected with each other and have apparently no common basis of technical system or scale, from which it will be difficult eventually to compile a satisfactory and homogeneous first map of our African possessions. A large amount of geographical work, carried on more or less under the auspices of the Royal Geographical Society, is gradually accumulating, all of which might be usefully turned to account in a general survey scheme, if uniformity of method and scale were adopted. A comprehensive scheme of geographical survey (apart from special surveys for local requirements), to be carried out jointly with other nationalities in the continent of Africa, will undoubtedly prove a necessity in the near future for purposes of boundary demarcation and administration ; but such a scheme must emanate from those responsible advisers of Government who are best acquainted with the opportunities for combined action and the means for carrying it out.

But, pending the adoption of such a scheme, and with due appreciation of the value of the disjointed efforts which are now being made to secure partial surveys for administrative purposes in various parts of the country, your Committee are of opinion that the following considerations, none of which involve immediate financial outlay, should be especially brought to the notice of His Majesty's Government ; inasmuch as immediate attention to them would undoubtedly tend to hasten the attainment of the end primarily in view—viz., the construction of a homogeneous and consistent geographical map of that part of Africa which affects Imperial interests.

(1) The advantage of a common scale should be impressed on local administrations who have already commenced surveys within the protectorates under their administration, and every effort should be made in the first instance to secure a general map on the smallest geographical scale which can be made practically useful for purposes of either administration or strategy. This scale should not be less than one in five hundred thousand.

(2) Inasmuch as all future surveys, on whatsoever scale, must ultimately depend on the accuracy of the initial base measurements if they are to fit together into one homogeneous map, it is most desirable to draw the attention of local administrators to this point ; and, wherever local surveys have already been commenced, to test the accuracy of their linear measurements by the adoption of a geodetic base. Such a base need not be measured by the cumbersome processes which have made the measurement of geodetic bases so laborious and expensive in the past. New

methods and improved means have lately been introduced which greatly simplify the work, but there is no method which does not require scientific direction. It would therefore be advisable that the same instruments, under the same personal supervision, should be used in every case. Unity of scale and of linear measurement is absolutely essential to final compilation in such vast areas as Africa presents, and much good work now in progress may be rendered valueless for general map-making purposes if such unity is not secured *ab initio*.

(3) It is the earnest desire of the Royal Geographical Society that those travellers and explorers who use their instruments and accept their assistance financially should add to the practical outcome of mapping material in Africa. For this purpose the Society has established training classes in practical geography, and keeps a record of the names of those who are qualified to work as geographical surveyors. But in order to utilise their work to the fullest extent it is essential that the geographical data determined by such professional surveyors as from time to time are sent to Africa under the direction of the Intelligence Department should become generally available; and it is therefore most desirable that all such material (indispensable for the proper location of field surveys and for check on final positions) as may be collated at the Intelligence Office may be placed at the disposal of the Royal Geographical Society. Attention should very specially be drawn to the great amount of geographical mapping (at present disconnected and wanting in topographical detail) which is annually turned out by irresponsible travellers. The value of this might be largely increased if it were based on exact data.

(4) One of the most important factors in dealing with the vast area of our African possessions in the matter of geographical (or first) surveys is the absolute necessity of resorting to native agency for its topography. Effective topography can never be secured without the assistance of surveyors and draughtsmen specially trained to this particular branch of map-making. European agency (except for purposes of supervision) is out of the question on account of the expense. Indian native agency is equally impossible for more than comparatively restricted areas. The vast mass of African mapping must be secured through the agency of natives of Africa, just as Asia has largely been mapped by Asiatics.

There is apparently no reason why natives of Africa, trained in mission and other schools, should not be as effective in the field of survey as Africans generally have proved in the field of arms.

It is suggested that in the earlier stages of the formation of such an agency scientific societies might be willing to take the initiative. It is to the interest of the Royal Geographical Society, for instance, to secure the assistance of native topographers for explorers. What is immediately wanted is the initiation of a training school; and it seems probable that, if one or two promising pupils were selected from each protectorate for training, an invaluable school would in a few years be established, which would rapidly extend of itself. The Commissioners and Administrators of our African Protectorates might be requested to assist in the experiment by ascertaining whether volunteers from the native schools can be found for the purpose. Every assistance to such a scheme may be confidently anticipated from the Indian Government, who have long had practical experience of the enormous advantages of native labour in the field of surveying.

Terrestrial Surface Waves.—First Report of the Committee, consisting of Dr. J. SCOTT KELTIE (*Chairman*), Lieut.-Col. BAILEY, *late R.E.*, Dr. VAUGHAN CORNISH, Mr. A. ROOPE HUNT, *F.G.S.*, Mr. W. H. WHEELER, *M.Inst.C.E.*, *and* Mr. E. A. FLOYER. (*Drawn up by* Dr. VAUGHAN CORNISH.)

THE following papers have been published by Dr. Vaughan Cornish since the Bradford Meeting, viz.—On the Formation of Wave Surfaces in Sand, 'Scottish Geographical Journal,' January 1901; On Sand-waves in Tidal Currents, 'Geographical Journal,' August 1901.

On December 4, 1900, Dr. Cornish left for Canada to study the surface forms of snow, returning to England March 16. During the voyage out, Liverpool to Boston, much heavy weather was encountered, and observations, with some measurements and photographs, were obtained of deep-sea storm-waves. On the return voyage, New York to Southampton, some good observations were obtained of the conditions obtaining in a heavy swell. A paper on ocean waves, embodying results obtained by Dr. Cornish during several years, is in preparation.

Canada was snow-covered during the whole of the expedition. The country was traversed from Montreal to Vancouver and back by the Canadian Pacific Railway. Special facilities were most kindly accorded by this railway company in the interest of pure science. The principal places of observation were Montreal, Winnipeg (Manitoba), and Glacier House (British Columbia), which afforded good opportunities for the study of the three principal kinds of snow surface which were encountered. The observations appear to divide themselves naturally under two heads: (1) snow-waves and ripples; (2) snow-drifts and snow-caps; and the results of the expedition are now being worked up under these heads.

The most striking point with reference to the trains of moving waves of cold, dry, drifting snow is that the place most favourable to their formation is an extensive level surface free from inequalities or obstructions, such as a frozen lake. Here most readily occur those local *surcharges* of snow which originate the long trains of waves. At first these travel freely, but their march and growth do not continue so long as is the case with the homologous waves of sand, because the snow readily sets into a coherent, though friable, mass. The height of these waves was generally not more than six inches. They are flatter than the homologous æolian sand-waves, the wave-lengths being often forty or fifty times as great as the amplitude.

Ripples, perfectly homologous with the æolian sand-ripples, are produced in the granular snow-stuff formed by erosion of consolidated snow. Their wave-lengths are similar to those of the sand-ripples, but their amplitude is less. There are also regularly undulating surfaces carved by the wind in more coherent snow, particularly when it is well stratified. The ridges retreat before the wind, keeping their steeper slope on the weather side. The material has an internal arrangement not imposed by the wave motion, and, so long as it is a part of the waved structure, is itself stationary. It is therefore fitting that these surfaces, which are frequent and regular, should have a distinguishing name, and it is proposed to call them *undulates*. The ratio of height to length in the undulates is greater than in the normal waves and normal ripples.

The most interesting drifts were those on the prairies, where the cold is great and the snow is dry. The normal snow-drift round a house on the open prairie in Manitoba consists mainly of a snow-bank in the form of a **U**, the house being situated in the bend, near the bottom of the letter, with a few yards nearly free from snow between it and the snow-bank. Between the two limbs of the **U**, which are much longer, reaching further to leeward, than the shape of the printing type permits to be here indicated, the ground is kept almost clear of snow by the operation of the wind as modified by the presence of the building, and this clearance is sometimes noticeable beyond the distance to which the two arms of the drift extend as a noticeable snow-bank. Close to the house, centrally situated on the lee side, is a relatively small accumulation of snow, which is, however, conspicuous from its form and position. Beyond the limbs of the **U**-shaped snow bank to right and left the depth of the snow on the prairie is not notably affected by the neighbourhood of the building. The height of the **U**-shaped snow-bank is commonly four to six feet when there are three or four inches of snow on the open prairie.

In the calm upper valleys of the Selkirk Mountains, where the snowfall is very heavy, the flakes usually large, and the temperature during precipitation usually near the melting point, the notable forms in which the material accumulates are not those of drift but deposition, not snowbanks but snow-caps. On tree stumps these frequently take the form of gigantic mushrooms, nine to twelve feet wide and four to four and a half feet thick, which project from three to four feet all round beyond their supporting pedestal. These strange growths are not unstable, as are the small globular masses of snow upon a slender support, but, on the contrary, possess a remarkable degree of permanence. The depth of snow in them is sufficient to express most of the air, and to weld the lower parts into a tenacious mass.

Much attention was given to overcoming the difficulties of the *real* photography of snow, *i.e.*, the rendering of the detail of the snow surface, instead of photographing objects silhouetted against snow, as is done in the ordinary 'snow-scene' photograph. After some initial failures success was achieved, and a large collection of good quarter- and half-plate negatives has been brought back which is of very considerable scientific value.

The whole of the grant has been expended, and the Committee apply for a grant towards the expenses of continuing the investigations.

Women's Labour.—First Report of the Committee, consisting of Mr. E. W. BRABROOK (*Chairman*), Mr. A. L. BOWLEY (*Secretary*), Miss A. M. ANDERSON, Mr. C. BOOTH, Professor S. J. CHAPMAN, Miss C. E. COLLET, Professor F. Y. EDGEWORTH, Professor A. W. FLUX, Mrs. J. R. MACDONALD, Mr. L. L. PRICE, Professor W. SMART, *and* Mrs. H. J. TENNANT, *appointed to investigate the Economic Effect of Legislation regulating Women's Labour.*

THE Committee, as appointed at the Bradford meeting, sought the assistance of Mrs. H. J. Tennant, late H. M. Principal Lady Inspector of Factories, Miss A. M. Anderson, her successor in office, Miss C. E. Collet, of the Board of Trade, and Mr. Charles Booth, to all of whom the

members of that Committee return their thanks for accepting the invitation to join them.

The Committee, as thus enlarged, resolved that it would adopt the classification of industries made by the Labour Commission, and would request some of its own members and some other competent observers to enter upon a local investigation of the question, as far as practicable, in every locality in which such industries were pursued by women.

It proceeded to prepare, for the use of the members and others thus commissioned by it, the following scheme of investigation :—

Scheme of Investigation for Commissioners.

Commissioners should be supplied with—

(1) Abstracts of legislation.

(2) Information already obtained by parliamentary or other inquiries.

Commissioners should then visit the industry and make themselves acquainted with the nature of the work, and especially with any changes which have taken place since the legislation for women began.

Commissioners should observe the following points in their investigations :—

I. The effects of the legislation *generally*.

(1) Has it necessitated or induced any alteration of custom, or merely enforced what was customary before, in the case of the *women* themselves, in the industry in question, or in others related thereto ?

(2) Has it necessitated any alteration in the case of *other workers* (men, young persons, or children) in the industry in question, or in other industries related thereto ?

II. The effects of the legislation *specially* on the position of women, whether (*a*) prejudicially :—

(1) Has it lowered the wages of women relatively, either temporarily or permanently ?

(2) Has it caused any displacement of women ?

(3) Has it initiated any important changes in the use of machinery or the division of labour ?

Or (*b*) beneficially :—

(1) Has it increased the efficiency of the women themselves as industrial agents; and is this efficiency due to all, or only to some, of the legal restrictions ?

(2) Has it increased their economic efficiency as members of society (*e.g.*, with relation to home life, the health of the children, the morality of the race), and are these effects due to all, or only to some, of the restrictions ?

(N.B.—The legislation may affect the demand for women's labour (1) directly, in the industry in question by adding to difficulties of management, or by diminishing the output of the women themselves, or of others engaged in the work; (2) indirectly, by effects on other industries related to the industry in question; or it may increase the supply of women and their substitution for men by rendering the work healthier or easier.)

Commissioners should endeavour to discriminate between changes affecting the employment of women which are due to the legislation and those which result from other causes.

The Committee awaits the reports of the several Commissioners, and would be glad to receive offers of assistance from any other persons who are able to procure and furnish the information sought with respect to any particular field in which women's labour has been regulated by legislation.

The Committee begs to thank the Secretary of State for the Home Department for having given permission to the Inspectors of Factories to furnish the information required with respect to their several districts.

The Committee received an offer of information from the Freedom of Labour Defence, of which it would be glad to avail itself.

As the reference to the Committee is general in its terms, and includes the economic effect of legislation in every country regulating women's labour, the Committee addressed the following circular to the heads of the statistical bureaux of various countries and to other persons of authority, not only in Europe, but also in the United States and the British Colonies.

Circular to Foreign and Colonial Authorities.

'The above-named Committee, having been appointed by the British Association to enquire into the economic effect of legislation regulating Women's Labour, are desirous of obtaining information relating to that subject in industrial centres outside of the United Kingdom, and have directed us to ask the favour of your assistance.

'They will be greatly obliged to you for any information you are able to furnish them in answer to the subjoined questions with regard to your own country.

'1. Did any enquiry precede the enactment of the statutes regulating women's labour? Kindly give full reference to any record of such enquiry.

'2. Has any enquiry been made into the results of such legislation since its enactment? Kindly give reference to records.

'3. What are the particular industries in which women's labour is regulated? And what proportion do women and girls employed in such industries bear to the whole industrial female population of the country?

'4. Are any statistics available with regard to the industries affected by such legislation of—

(*a*) The number of women employed	(A) At or shortly before the date of the enactment?
(*b*) The wages paid to them	(B) At or shortly before the present time?
(*c*) The number of men employed	(C) At any intermediate period?
(*d*) The wages paid to them	
(*e*) Other economic data	

Kindly give full references to records.

'5. Can you favour the Committee with any observations of your own on the matter?'

The Committee has received from its foreign correspondents a great quantity of valuable information, for which it has returned its thanks.

The Committee has thus taken the necessary preliminary steps towards the investigation of the subject referred to it. The subject is a large one,

and the investigation will no doubt occupy some time. The results of the census recently made in the United Kingdom will have a direct bearing upon it. The Committee does not think it would be advantageous to publish in the present preliminary report any of the particulars as yet obtained, either with relation to the United Kingdom or to foreign countries.

The Committee therefore asks to be reapppointed in order that it may pursue the investigation.

The Resistance of Road Vehicles to Traction.—Report of the Committee, consisting of Sir ALEXANDER BINNIE (*Chairman*), Professor HELE-SHAW (*Secretary*), Mr. AITKEN, Mr. T. C. AVELING, Mr. J. BROWN, Professr HUDSON BEARE, Mr. W. W. BEAUMONT, Colonel CROMPTON, Mr. A. MALLOCK, Sir DAVID SALOMONS, Mr. A. R. SENNETT, Mr. E. SHRAPNELL SMITH, Mr. J. I. THORNYCROFT. (*Drawn up by the Secretary.*)

AT the first meeting of the Committee it was decided—

1. That an experimental car and dynamometer were necessary for performing the experiments on road traction.
2. That members of the Committee should be invited to state their views in writing concerning the mode in which the experiments should be carried out.
3. That ultimately, with a view of obtaining results on different types of roads, trials should be conducted at three centres where facilities could be obtained—namely, Aldershot, Cupar in Fifeshire, and Liverpool.
4. That a summary of all work hitherto done in the investigation of road resistance should be prepared by the Secretary.

At the same meeting Mr. J. Brown, of Belfast, offered to alter the viagraph, which is the self-recording instrument of his own invention, in order to make it specially suitable for carrying out the experiments, and to place it at the disposal of the Committee. Other members of the Committee, amongst them Mr. Aitken and Colonel Crompton, undertook to carry out experiments with the special facilities at their command.

At a subsequent meeting the suggestions contributed by various members of the Committee were fully discussed, and it was decided that in order to undertake experimental researches in a thorough and complete manner it would be necessary to raise a sum of about 1,000*l*. The Committee felt that, in view of the great development of mechanical traction upon roads, the scope of the report should not merely be limited to experiments on tractive resistance, but should deal with the effects of vehicles upon road surface of various kinds, and should involve experiments, not only with two different kinds of tyres, but with varying loads and speeds and with different types of vehicles.

An investigation would be undertaken concerning the relative effect upon the roads of various forms of mechanical traction and the best types of road for this purpose. They might therefore look with confidence to substantial pecuniary support from makers and users of traction engines and manufacturers of motor vehicles. The Committee might also reasonably expect substantial pecuniary support from various County Councils

and Local Boards. A circular was drawn up with this end in view; but pending the consent of the General Committee an application for funds in the above directions has not been pressed.

The step has been taken, however, of appointing Mr. T. C. Aveling, a member of the Committee, who is conversant with the traction-engine world, as Hon. Treasurer.

Meanwhile, an offer having been received from Sir David Salomons to lend to the Committee for an indefinite period, to alter as they pleased, a motor-car, it was determined in accepting this kind offer to proceed at once with a series of preliminary experiments, which would pave the way for future and more complete investigations. During the past few months work has been steadily proceeding upon the motor-car, the cost of new engines for which is being defrayed by Sir D. Salomons. Although great delays have been experienced with the engines, it is hoped that very shortly a preliminary series of the experiments may be commenced. These it is proposed to make in the first place with single wheels, with different kinds of tyres. The track for this purpose in the first place would be artificial, consisting of different kinds of materials laid in a trough or trench, about eighteen inches or two feet in width, so that the dynamometer itself can be thoroughly tested when the car is running upon a road of level surface.

In this way the autographic records obtained for materials, such as sand wet and dry, loose stones, artificial projections of cross pieces of wood of different sizes and differently pitched, can be thoroughly understood and constants of the dynamometer obtained, so as to enable the actual road trials to be made without unnecessary delays.

This the Committee consider to be very important matter, since the difficulties involved in securing permission to make, and in actually making, trials upon the roads themselves should be reduced to a minimum. The new viagraph of Mr. Brown has been received and is awaiting these trials. It has been altered by the important addition of a device for attaching different curved surfaces, representing segments of wheels of different diameters. The rise and fall of this curved piece is autographically recorded, and from experiments which have already been made by Mr. Aitken it is clear that the actual contour of the road or surface being experimented upon can be clearly indicated at the same time that the actual resistance is being recorded by the dynamometer. The Committee have not thought it advisable in the present report to publish a detailed description of the dynamometer, since the instrument may possibly undergo considerable modification in the course of the experiments. Further, they consider that in view of the fact that the work of different experimenters on road resistance (an abstract of which has, in accordance with their instructions, been prepared) consists in many cases in the enunciation of laws and formulæ, it will be better, instead of publishing at the present juncture this abstract, to wait until their own experiments can be compared with those of previous workers, particularly as, for the first time, it will be possible to make observations at any required speed from the highest to the lowest velocities of practical interest.

The grant of money already given will not be sufficient to cover expenditure already incurred; therefore they make application for a further sum of equal amount (viz., 75*l.*), with permission to raise the additional sum they require, and for the reappointment of the Committee.

APPENDIX.

Abstract of Suggestions.

Mr. Aitken

(*a*) The dynamometrical apparatus for recording the different conditions in the resistance of road vehicles to traction would require to be self-contained; that is, a separate machine on wheels or an apparatus attached to the loaded vehicle. For slow-travelling traffic all the different items which go to make the net result might, with the exception of vibration, be accommodated on an apparatus with wheels, placed between the prime mover and the vehicle hauled. For fast-travelling traffic such an apparatus could not, he imagines, be used with safety, so that the appliance would require to be fixed to the motor or loaded vehicle. At a high velocity the viagraph would not be available, but records could be made previous to carrying out the experiments with the road vehicles. The connecting appliance would require to be short-coupled in order to reduce oscillation.

(*b*) The scheme of experiments would cover all descriptions of pavements and macadamised roads. In the experiments the viagraph must play a conspicuous part; and if the speed, pull, and vibration could be autographically recorded to correspond with the 'viagram' the different conditions could be seen at a glance, while a scale of measurements would give definite results.

For experiments at high speeds a viagraph section would require to be made first, a record taken one way corresponding with the exact position which would be occupied by the vehicle, and another back and corresponding with the width between the wheels of the vehicle, so as to arrive at a mean value of the irregularities of the road surface. A distinctive mark made by the viagraph in previously passing along the road would guide the driver of the experimental vehicle in following the proper course.

The pull, &c., on the best laid asphalte pavement might be taken as the standard to work from, and which in all probability would give about 5 feet per mile of unevenness.

Each road surface from that point and for each succeeding 5 or 10 feet per mile up to 100 feet of irregularity could be tested on level stretches and on gradients at different speeds to ascertain the pull required and the amount of vibration.

The extent of the unevenness recorded by the small wheel of the viagraph, and that of wheels of varying diameter, could be ascertained experimentally, from which, no doubt, some kind of formula could be deduced.

Mr. Aveling :—

The Sub-Committee might be divided for the purpose of making trials into—

(*a*) In heavy or road locomotive class;
(*b*) In medium or steam lorry class;
(*c*) In automobile or light class;

so that the experiences of each of the sub-Committees in their own particular line should be more directly available.

Mr. W. Worby Beaumont :—

A. Resistance to be obtained by a, say, 8-horse power Daimler car hauling:

(*a*) A light two-wheeled vehicle with iron tyres and

1. Running light.
2. With 3 cwt. load.
3. With 6 cwt. load.

(*b*) A light four-wheeled vehicle with iron tyres. Tests same as above for two-wheeled trap.

(*c*) A heavier type of two-wheeled vehicle with iron tyres and 10 cwt. and 1 ton loads.

(*d*) A heavier four-wheeled vehicle, same load.

B. Hauling vehicles same or similar to (*a*), (*b*), (*c*), (*d*), but with

(*a*) Solid rubber tyres.
(*b*) Pneumatic tyres.

C. Iron-hoop tyres to be shrunk on vehicles in (*a*), (*b*), (*c*), (*d*), of double width makers ordinarily put on same, and same tests again made.

D. Trials of two-wheeled vehicles to be made with two different sizes of wheels, say 38 inches and 48 inches.

E. Angle of draught to be at least two, say (1) horizontal, *i.e.*, level with axle; (2) upward inclination of, say, 20 degrees. Trials made with skeleton vehicles, all tests to be made (1) on level, smooth asphalte; (2) on all sorts and conditions of other level roads; (3) on all sorts of roads of different grades.

Speeds to be the four speeds of the hauling car.

Mr. J. Brown :—

The surface of the roads upon which the experiments are to be made should be tested in two particulars :—

(*a*) The smoothness.
(*b*) The hardness.

The smoothness of the roads should be tested by means of his viagraph, to which he suggests the addition of a skate with the curved outline corresponding to a wheel.

For the hardness an apparatus in which the weighted stamper is raised and lowered at intervals might be used, the amount of yield in the road being autographically recorded.

Mr. A. Mallock presented a design for a dynamometer using a single wheel. The arguments for such were as follows :—

(*a*) This requires at most only half the number of experimental wheels.

(*b*) Changes from one form of wheel to another can be made more rapidly.

(*c*) The tractive force can be more regularly measured.

(*d*) The effective load carried by the wheel can be known with certainty.

Mr. Mallock's designs for the single-wheel dynamometer may be

roughly said to consist of a castor frame in which the single wheel is held, the wheel being capable of being loaded to any required amount. The castor frame is attached to the tractor, the pull on the wheel or tractive force being taken through a bell crank frame on to a small ram, so that by fluid pressure the tractive force can be continuously recorded.

The following are Mr. Mallock's general suggestions :—

1. Variable radius of wheel, load, and speed. Begin with five wooden wheels, with iron tyres 2 inches wide ; diameter of wheels, 5 feet, 4 feet, 3 feet, 2 feet, 1 foot. These to be tried each with increasing loads, beginning, say, at 500 lb., and at two, four, six, eight, and ten miles per hour.

In the first few sets of experiments small increments would be made of the loads, as it is probable that for each kind and state of road there may be one or more critical pressures. Experience will show how large the increments may be without loss of accuracy in the resistance-in-terms-of-load curve. If suitable apparatus is used it might be expected that a complete series of experiments, both for variations of radius and load, could be completed in a day.

2. The experiments should be repeated with the roads in various conditions of wetness. After the variations of resistance in terms of radius and load have been well worked out, one or two diameters might be selected with which to try variations in the width of the tyre. The widths should range from 1 inch to 10 inches.

3. Trials might then be made of various classes of tyres, such as solid rubber, pneumatic tyres, &c.

4. Some method should be devised to classify and describe the condition of the roads.

5. Every series of experiments should begin and end with a trial of some particular wheel for the sake of reference.

Sir David Salomons :—

All vehicles to be loaded to 1 ton, $1\frac{1}{2}$ or 2 tons, as the case may be, to avoid calculations.

Gradients to be taken by percentages, say 2, $2\frac{1}{2}$, 5, $7\frac{1}{2}$, 10, $12\frac{1}{2}$, and 15 per cent.

Nature of surface classified, such as asphalte dry, wet, and greasy ; wood dry, wet, and greasy ; macadam dry, wet, muddy, freshly laid, worn, very worn.

Experiments to be made on roads laid with syenite, granite, Maidstone stone, Sevenoaks gravel, flint.

Also when rough laid before rolling and after rolling.

Also cinder, sand, beach, and other roads.

Traction measured when from standstill at two, five, ten, twelve, fifteen, eighteen, twenty, twenty-five, and thirty miles per hour.

Wind and air resistance to be calculated from actual registering apparatus to give net results and air resistance.

Air experiments might further be made thus :—

Flat front of vehicle and same at back built of light board.
Front conical to cut air and back flat.

Front and back both conical.

Wheels might be steel, solid rubber, pneumatic tyres, flat, and rounded.

Various diameters of wheels, those generally adopted, and a few trials

with wheels of greatly larger diameter, say 6-foot front and back wheels equal, and of different diameters, first larger in front, then larger behind.

Small Screw Gauge.—Report of the Committee, consisting of Sir W. H. PREECE (*Chairman*), Lord KELVIN, Sir F. J. BRAMWELL, Sir H. TRUEMAN WOOD, Major-Gen. WEBBER, Col. WATKIN, Lieut.-Col. CROMPTON, A. STROH, A. LE NEVE FOSTER, C. J. HEWITT, G. K. B. ELPHINSTONE, E. RIGG, C. V. BOYS, J. MARSHALL GORHAM, O. P. CLEMENTS, W. TAYLOR, Dr. R. T. GLAZEBROOK, *and* W. A. PRICE (*Secretary*), *appointed to consider means by which Practical Effect can be given to the introduction of the Screw Gauge proposed by the Association in* 1884.

THE Committee report that the present condition of the matter submitted to them is as follows :—

In the report presented at the meeting of the Association which was held at Bradford in 1900 it was recommended that the shape of the thread of the British Association screw gauge for the use of instrument makers should be altered in the following particulars for all screws from No. 0 to No. 11 inclusive.

For screws.—That the designating numbers, pitches, outside diameters, and the common angle of $47\frac{1}{2}^{\circ}$ remain unchanged ; but that the top and bottom of the thread shall be cylindrical, showing flats in section, and that the depth of the thread shall be increased by one-tenth of the pitch, the diameter of the solid core being in consequence diminished by one-fifth of the pitch.

For nuts.—That the designating numbers, the pitches, the diameters of the clear holes, and the common angle of $47\frac{1}{2}^{\circ}$ remain unchanged ; but that the top and bottom of the thread shall be cylindrical, showing flats in section, and that the depth of the thread shall be increased by one-tenth of the pitch.

The effect of these alterations is as follows :—

The threads of the screws and taps are of a very simple form, being cut with a single point tool or grinding wheel, with straight sides and a flat top, and the top of the thread is part of a cylinder. Though the form of the bottom of the thread depends on the correct grinding of the end of the tool, great accuracy is unimportant, as the screws and nuts do not come into contact there.

The threads of the nuts and ring gauges will be accurate in proportion as are the taps used to cut them, the edge of the thread forming the through hole being part of a cylinder.

The actual differences between the screws and nuts of the old form and that recommended are so small that it is believed the old stocks will in practice be interchangeable with the new screws, so that the amount of inconvenience caused by the change will be exceedingly small.

The British Association screw gauge has been in use in England for seventeen years. Many firms in England have originated the threads and constructed gauges for sale or for their own use, but the difficulty of producing them is great, and the market obtainable may have been

insufficient to induce them to perfect the processes necessary for making them accurately interchangeable. In short, the British Association screw gauge of 1884 was of too complicated a form to allow of its accurate realisation except at a cost which has proved prohibitive.

That very accurate gauges with rounded threads can be produced is not disputed, but the difficulty of doing so for small screws is very great. The names of three firms in America and of one in Germany have been proposed to the Committee as being competent, and probably willing, to undertake the production of gauges and tools of the rounded thread. The Birmingham Small Arms Company, who produce interchangeable work on a very large scale, and to a high degree of perfection, use only round-topped screws, fitting all over, for bicycle work; and Mr. Clements exhibited gauges used by that firm illustrating his paper read before the Section at Bradford. This firm does not produce these gauges for sale. The American firm of Pratt & Whitney have manufactured a large number of sets of gauges and screwing tools for the English Government, but declined to submit these to the Committee on the ground that they were not sufficiently accurate to satisfy us. After long delay they submitted to us three specimens, which were reported upon by this Committee at the Dover meeting. Though the best we had seen, they were distinctly inferior to the screws used in the ordinary micrometers purchasable in tool shops, which have threads of the character which this Committee has recommended for adoption.

While the round thread is only produced satisfactorily by a very few firms, who have made a special study of this class of work, the Committee believe that the form of thread they have proposed can be made in any fairly equipped tool room; and that this facility in producing or obtaining the necessary appliances must very greatly encourage the maintenance of an accurate standard in small screws, to promote which has been the object in the view of the Committee. If, on the other hand, these tools and gauges are very special, and perhaps costly, appliances, obtained only by the refined processes of certain factories, their use in workshops will extend slowly. The Committee aim at putting the matter on such a footing that the common everyday appliances in the hands of workmen shall be of a good order of accuracy, and this is only possible if they are produced easily and cheaply.

It is not suggested by the Committee that the form of thread recommended is the best for all purposes and for all sizes of screws, and they have expressly excluded sizes of screws below No. 11 British Association gauge, which are produced by pressure and not by cutting. Their recommendation applies only to the screws used in instrument making and similar trades for assembling parts, of which screws a large proportion—perhaps 95 per cent.—are of brass. Considerations affecting the use of screws for other purposes have been put before the Committee, especially by Mr. Clements in the case of bicycle and gun screws, and by Mr. Taylor in the case of lens screws. These have thrown suggestive light on the question before the Committee, and will be closely considered by them if reappointed.

Since the last report the Committee's proposals have attracted much attention, but no sets of gauges or tools of the new thread have been submitted to them, and so far their recommendation has had no practical result. They are informed, however, that one firm of manufacturers in England is occupied in producing tools and gauges for their own use, and

if they succeed in producing them of satisfactory accuracy will submit them to the Committee.

Mr. O. P. Clements, the author of a paper on screw threads used in bicycles, read before the Section at Bradford, has been elected to the Committee.

Mr. W. Taylor, who has taken a leading part in the standardisation of the screws of photographic lenses, and has been in communication with the Committee, has also been elected a member.

Dr. R. T. Glazebrook has been elected a member of the Committee.

Correspondence has passed between the Committee and Dr. R. T. Glazebrook, the Director of the National Physical Laboratory, respecting the examination of screw gauges, and the following arrangements have been made:—

The National Physical Laboratory will undertake to examine and to report upon gauges of the British Association submitted to them.

The Committee have applied the grant of 45*l.* made to them at Bradford to the purchase of apparatus for the examination of gauges by the National Physical Laboratory, and have appointed Mr. C. V. Boys, Lieut.-Colonel Crompton, Dr. R. T. Glazebrook, Mr. W. A. Price, and Colonel Watkin to be a sub-Committee for the expenditure of the grant. The Committee are of opinion that the previous grant of 45*l.*, made in 1900, will be insufficient to purchase the necessary apparatus, and recommend their reappointment, with a grant of 45*l.*

Ethnological Survey of Canada.—Report of the Committee, consisting of Professor D. P. PENHALLOW (*Chairman*), *the late* Dr. GEORGE M. DAWSON (*Secretary*), Mr. E. W. BRABROOK, Professor A. C. HADDON, Mr. E. S. HARTLAND, Sir J. G. BOURINOT, Mr. B. SULTE, Mr. C. HILL-TOUT, Mr. DAVID BOYLE, Mr. C. N. BELL, Professor E. B. TYLOR, Professor J. MAVOR, Mr. C. F. HUNTER, *and* Dr. W. F. GANONG.

IN recording the work of the past year we are called upon to notice the very sudden decease of Dr. G. M. Dawson, which occurred at Ottawa on March 2, 1901, as the result of bronchitis. Dr. Dawson had been identified with the work of this Committee from the time of its organisation, and he served at first as its Chairman, and later as its Secretary, which position he held at the time of his death. His well known ethnological studies in connection with the Indians of the Pacific coast and the keen practical interest which he constantly manifested in the prosecution of such work gave special weight to his connection with this Committee the object of which commanded his warmest sympathy and his deepest interest; and we are keenly sensible of the great loss we have sustained in the removal of one whose broad interest in the progress of scientific research, and whose intelligent appreciation of the many difficult problems connected with the prosecution of ethnological work in a country where the conditions are changing so rapidly, gave him exceptional qualifications for the guidance of our work and imparted to those especially engaged in collecting data a never-failing stimulus and enthusiasm.

Renewed negotiations with certain of the provincial Governments have been opened during the year with a view to having the work of this Committee placed upon a more permanent basis, and it is hoped that favourable results may appear before our next annual report is made.

Dr. Ganong has undertaken the organisation of systematic work in New Brunswick, with special reference to the remnants of Indian tribes in that section of the country, and a somewhat definite statement of progress in this direction may be anticipated for the next report.

The anthropometric work of the Committee has been in progress for the last three years, and material is steadily accumulating which will ultimately be placed in competent hands for final analysis.

Mr. Léon Gérin, whose very acceptable work upon the Indians of Lorette was reported upon last year, has continued his studies with reference to the Iroquois of Caughnawaga; but the material is not sufficiently advanced to make it available for the purposes of the present report.

Mr. A. F. Hunter has shown continuous activity in the ethnology of Ontario. He has published in the 'Archæological Report of Ontario' for 1900 his third contribution to the bibliography of Ontario archæology. In volume iii. of the 'Ontario Historical Society' he has also published an article on 'The Ethnographical Elements of Ontario.' This paper was prepared in the line of the investigations of this Committee, and, as in the case of the contributions by Mr. Sulte, it will serve as an important basis for further investigations. Its importance and the fact that the place of first publication would secure only a limited circulation made it desirable that a certain number of extra copies should be secured by the Committee for use in its special work. These are now available, and a copy is transmitted herewith.

Mr. Hill-Tout has continued his studies of the Salish tribes of British Columbia. His report for this year deals chiefly with the Halkōmē'lem tribes of the Lower Fraser. The evidence, both from his archæological investigations and from his linguistic studies, leads him to conclude that these tribes are comparatively late comers in their present territory, and that the original undivided home of the Salish stock was not on the shores and bays or tidal rivers of this coast, each tribe or division having separate and distinct names for the various kinds of fish and other marine products, which could not conceivably have been the case had they lived together here, since fish formed the principal portion of their food from time immemorial, as their midden-heaps testify. Their stories and myths accounting for the origin or presence of the salmon and other forms of marine life in these waters are also widely dissimilar, plainly showing that they have been independently evolved since the separation of the tribe into its present divisions.

Another important result has been reached by a comparative study of the philosophy and social customs of the Salish tribes. It has been found that their beliefs and customs furnish us with the steps by which the peculiar totemism of the northern tribes of this coast is reached. It is seen to be the natural outgrowth and development of an earlier fetishism, the different cultural planes of the Salish presenting very clearly the intermediate steps by which the former gave rise to the latter.

The linguistic part of the report, to which the author has devoted much time and study, forms a valuable addition to our knowledge of the Salish tongue. It presents a comprehensive exposition of the grammatical structure of two important dialects of this family, to which are added examples of native text and extensive glossaries of Kwa'nthen and Teil'qēuk terms.

The Committee desire to be reappointed, with a grant of 30*l.*, in addition to the balance of $46.15 in hand. The Committee recommend

that Mr. C. Hill-Tout, of Abbotsford, British Columbia, be appointed Secretary, and the Rev. John Campbell, of Montreal, a member of the Committee.

Natural History and Ethnography of the Malay Peninsula.—Second Report of the Committee, consisting of Mr. C. H. READ *(Chairman),* Mr. W. CROOKE *(Secretary),* Professor A. MACALISTER, *and* Professor W. RIDGEWAY.

THE Committee have received the following report from Mr. W. W. Skeat, the leader of the expedition in continuation of the report presented last year :—

Second Report on Cambridge Exploring Expedition to the Malay Provinces of Lower Siam. Drawn up by W. W. SKEAT.

In continuation of my report of last year (in which the route taken by the Malay States Expedition was described) I have the honour to forward a report descriptive of the ethnographical material collected in so far as it is possible for me to do so under existing conditions.

I propose also, for convenience' sake, to preface the ethnographical part of the report with a few general remarks on the collections made in the other departments of science which were represented on the staff of the expedition.

Notes on Zoology.

Zoology.—An extensive collection of Vertebrates was made, but this group has been, comparatively speaking, so well worked that the interest of the collection is more likely to consist in extending the range of species already known than in the making of new or startling additions to our existing information about the Peninsula. About three or four new species have, however, already been reported.

A few of the most interesting points about the entire collection, from a zoological point of view, are :—

1. The discovery of the first two species of *Peripatus* found in the Malay Peninsula.

About thirteen specimens of Peripatus (comprising two species) were collected by members of the expedition.

The first species was first collected on Bukit Besar (3,000 ft.), in Patani, by Mr. R. Evans, and the second some time later by Mr. F. F. Laidlaw at Kuala Aring, in Kelantan, both localities being in the East Coast States. A third species was collected some months afterwards (and independently of the expedition) by Mr. Butler in the West Coast State of Selangor. All three species are included by Mr. Evans in a new genus which he has called 'Eoperipatus.' [1]

A point of great interest (Mr. Evans tells me) is that in the earlier stages of development (*e.g.*, in the size and structure of ovum) they resemble the Australian forms, but at a later period (*e.g.*, in the size of embryo at birth), they more nearly approximate to the American forms, to which anatomically they also bear so strong a resemblance that they have been included in the same sub-family (of Peripatidæ). Mr. Evans

[1] *Quart. J. Micr. Sc.*, vol. xliv., Pt. IV. n.s.

concludes that the Peripatidæ must once have had a common centre of distribution either in Africa or in some lost continental tract which formerly afforded a means of land communication between Africa, the Malay region, and South America.

2. The collection of Spiders and other Arachnids, of which more than one third have been determined as new by M. E. Simon (Paris), the great authority on this group.

3. The collection of Insects.

4. The collection of Oligochæta (the majority of which are new).

5. A good piece of work is Mr. Evans's account of the formation of the gemmule in *Ephydatia*.

The information about the rest of the collection is not yet fully available. I append, however, for convenience' sake, a table showing the groups to which the specimens collected belong, together with a list of the authorities who have kindly consented to work them out.

Freshwater Sponges	1 new species	Described as *Ephydatia blembingia* by R. Evans, M.A., B.Sc., in 'Quart. Jour. Micr. Sci.,' vol. xliv. p. 71
Marine Sponges	Few	Miss I. Sollas
Medusæ	2 or 3	R. T. Günther (Oxford)
Alcyonaria	Few	Professor S. J. Hickson (Manchester), M.A. (Downing College)
Turbellaria	Many species, mostly new	F. F. Laidlaw, B.A. (Trinity College)
Cestoda, Trematoda, Nematoda	Few	A. E. Shipley, M.A. (Christ's College)
Oligochæta	Not less than 16 species, of which at least 10 are new	Described by F. E. Beddard, M.A., F.R.S., in 'Proc. Zool. Soc.,' 1900, p. 891 [1]
Polychæta	Few	A. Willey, M.A., D.Sc.
Sipunculoidea	Probably 4 or 5 species	W. F. Lanchester, M.A. (King's College)
Crustacea	Considerable number	" "
Peripatus	Two species	R. Evans, M.A. ('Q. J. Micr. Sc.,' vol. xliv., Pt. IV. n.s.)
Myriapoda	Few	F. G. Sinclair, M.A. (Trinity College)
Arachnida	Not less than 139 species, of which 48 species and 4 sub-species are new	E. Simon (Paris) v. 'P.Z.S.,' 1901
Insects	—	Paper on habits by N. Annandale, in 'P.Z.S.,' 1900, p. 837
Lepidoptera	—	Professor E. B. Poulton, F.R.S. (Oxford)
Hymenoptera		P. Cameron v. 'P.Z.S.,' 1901
Hemiptera		W. L. Distant
Orthoptera (part)		M. Burr (Oxford)
Orthoptera (Phasmidae)		D. Sharp, F.R.S.
Odonata (Dragon-flies)	About 60 species, probably 10 new	F. F. Laidlaw, B.A.
Coleoptera		D. Sharp and F. F. Laidlaw
Mosquitos		F. V. Theobald, M.A. (St. John's College)

[1] Cp. also F. E. Beddard on a freshwater Annelid of the genus *Bothrioneuron* [*B. iris*, n. sp.] in Pt. I. 1901 (p. 81) of the *P.Z.S.*

Lamellibranchiata and a few other Molluscs	About 70 species	E. A. Smith (British Museum)
Other Molluscs (Gasteropoda, &c.)	Including about 20 species of terrestrial Operculates, of which probably 6 or 7 are new	F. F. Laidlaw
Other Molluscs (Slugs, &c.)	About 25 species, probably 5 or 6 new	W. E. Collinge (Birmingham)
Cuttle-fishes	2 or 3	W. E. Hoyle, M.A. (Manchester)
Fishes	Numerous	L. W. Byrne, B.A. (Trinity College)
Amphibia	About 29 species (none new)	Described by F. F. Laidlaw in 'P.Z.S.,' 1900, p. 883
Reptiles	Not less than 80 species, 2 or 3 probably new	F. F. Laidlaw
Birds	About 140 species	Paper by J. L. Bonhote, B.A. (Trinity College), 'P.Z.S.,' Pt. I. 1901, p. 57
Mammals	About 55 species, 1 new	Described by J. L. Bonhote, B.A. (Trinity College), in 'P.Z.S.,' 1900, p. 869

Specimens not yet distributed.

Corals	Considerable number	Probably J. S. Gardiner, M.A. (Caius College)
Echinoderms	Moderate number	Unassigned. These were to have been described by F. P. Bedford, B.A. (King's College), who died October 1900
Nemertines	2 or 3	Possibly R. C. Punnett, B.A. (Caius College)
Hirudinea	—	Unassigned
Polyzoa	1 or 2 species	? S. F. Harmer, F.R.S.

Botany.

Upwards of 1,000 species of dried plants were collected—about 430 by Mr. Gwynne-Vaughan and upwards of 600 by Mr. R. H. Yapp.

I understand from Mr. H. Ridley, M.A. (Superintendent of Gardens and Forests, Singapore) that both collections include specimens of much interest.

In both cases the specimens consisted mainly of Phanerogams and Vascular Cryptogams. They included a number of new flowering plants and probably one or two Ferns.

Messrs. Gwynne-Vaughan and Yapp have both been engaged in anatomical research on the material, preserved in spirit, collected during the expedition.

A small collection of Algæ have been distributed between Messrs. F. F. Blackman and G. S. West, both of St. John's College, Cambridge.

A few Fungi were also collected. They will probably be undertaken by Mr. R. H. Biffen, of Emmanuel College.

Geology.

With regard to the progress made in dealing with the geological specimens, Professor T. McKenny Hughes kindly sends me the following notes :—

The occurrence of fossils on some of the images of Buddha suggested a search for the quarry from which the rock was obtained out of which the images were carved, and it was at length found on the western flank of the great central axis of the Peninsula. The finer rock is in places highly fossiliferous ; the coarser has so far yielded only traces and suggestions of organisms. The collectors very wisely brought back large lumps of the portions which appeared to be fossiliferous, and by breaking these up with greater care than could have been used in the field, we have obtained a sufficiently large number of well preserved species to enable us to determine the geological horizon of the deposit.

There is a trilobite (Proetus), encrinite stems and arms ; several species of lamellibranchs and of brachiopods, among which last there is at least one species of Chonetes. There is a well preserved and highly ornamented Pleurotomaria and a Cephalopod, which, by its horseshoe lobes, confirms what is suggested by the general facies, namely, that the deposit belongs to the highest beds of the Carboniferous, or rather, perhaps, to beds intermediate between the Carboniferous and the overlying system to which the compromise name of Permo-Carboniferous has been applied. The rocks brought home fall into two divisions : (1) a grit of varying coarseness, consisting almost entirely of siliceous grains with occasionally larger included fragments of quartz and some foreign material ; and (2) a very fine rock in which, however, the constituents appear to be the same as those in the coarser rock, only more finely divided. Both rocks are jointed, and the joints are often picked out by bright coloured oxides, and in the case of the coarser rock by thin mineral veins in which limonite is conspicuous. The microscopic examination of both finer and coarser rocks confirms the views suggested by the macroscopic examination of the coarser specimens. The chemical analysis shows that the rock is almost entirely composed of silica, but it is evident that it has undergone much mechanical and chemical alteration. There are evidences of strain throughout ; the fossils are distorted, and some of the larger pebbles are broken and the parts displaced by movements in the rock. It is clear also from the character and condition of the fossils that there must have been originally much carbonate of lime in the rock furnished by large lamellibranchs and thick-shelled brachiopods. The cavity where the shell was is sometimes found lined with silicates, whereas no trace of the carbonate of lime remains in it. The absence of carbonate of lime was suggested by the sharp and undecomposed appearance of the carved work which, though it had evidently been exposed to the weather and the action of vegetation, nowhere showed the fretted surface of a calcareous rock.

ANTHROPOLOGY.

Notes on

I. *Anthropometry.*

There was so much heavy work to be done in other departments that but little time could be devoted to this branch of science.

Such statistics, however, as it was possible to compile should be of

especial interest, since it appears to be the first time that any systematic observations have been made on the Malays of the east coast of the Malay Peninsula.

As far as I have ascertained at present, about forty-four natives in all were measured. Of these about thirty were East Coast Malays, and the remainder (with the exception of one wavy-haired Sakai woman) were aboriginal jungle-dwellers, with the dark skin and frizzly hair of the Negrito type.

Upwards of twenty measurements were taken in the case of each individual, and a number of observations were made with reference to the colour and condition of skin, hair, and eyes, as well as various particulars bearing on the life of the individual measured.

The full measurements have not yet been thoroughly worked out, but the records of height appear to be thoroughly consistent in indicating the presence of two quite different standards of racial stature: (*a*) a high one, (*b*) a low one.

(*a*) From 159–166 C.; (*b*) from 151–156 C.

This largely confirms what has been written about the people of the East Coast States by Mr. Hugh Clifford and others; indeed, the difference of type is so marked that it could hardly fail to strike the ordinary observer.

The men belonging to the first type—

(*a*) Are tall, fleshy, raw-boned, and bulkily made men, somewhat resembling the Maori in general build.

Those belonging to the second type—

(*b*) Are short, with spare frame and comparatively slender lower limbs—as different as a polo pony from a plough-horse.

The taller type largely predominates in the East Coast States of Patani, Kelantan, and Trengganu, the centre of its racial focus lying in the most central of the three States referred, *i.e.*, in the State of Kelantan.

Notes on

II. *Ethnography.*

An examination of the ethnographical specimens has served to emphasise the importance of the area traversed, as one of the most vital of the connecting links between Asiatic civilisation and savagery. An interesting point is that this offshoot of the Mongolian race has adopted a culture which appears to be almost fundamentally Indian.

Another point to which perhaps justice has hardly been done consists in the immense value to Great Britain of her Malayan dependencies, the volume of whose trade (not including Borneo and Sarawak) amounted in the year 1900 to 51,900,000*l.*,[1] a figure which only falls short by a few millions of the great import and export trade of Canada, which in the same year amounted to 64,000,000*l.*[2] Most of this trade is certainly made by the Chinese; but even apart from the commercial question, and on merely general grounds, I think it is now being recognised that the work of understanding our native fellow-subjects possesses a high practical value, not only for science, but for government and trade, a

[1] Reckoning the dollar at 2*s.* [2] Reckoning the dollar at 4*s.*

notable instance of which was to be seen in the labours of the late Miss Kingsley.

With the additional material collected during the expedition it will now, I think, be possible to lay the foundations of a reasonably exhaustive ethnographical work dealing with the Malays of the Peninsula, their habits and customs, their religion and their industries. For this work I have already commenced to arrange the material. It would give me much encouragement to feel that I had the approval of the Association in this laborious task, which I have taken upon myself solely because work of this particular description is unfortunately so unremunerative under present conditions that nobody else could be found to undertake it at all.

As regards the method adopted for dealing with the material, my object is to have all special points which lend themselves to such treatment worked up by specialists in each particular branch of knowledge, a method which, I trust, will give an increased value to the ultimate result. Among those specialists who have most kindly undertaken to work up special sections I may mention Dr. R. J. Lloyd, of Liverpool; Mr. W. L. H. Duckworth, Professor Wm. Ridgeway, Mr. H. Warington Smyth, Mr. W. Rosenhain, Mr. H. Ling Roth, and others.

I shall proceed to a description of the material collected, though it is, I fear, impossible to give a really adequate description of the collection within the limits of the present paper.

Dress.

The working dress of the jungle Malays in Kelantan and Patani was of the scantiest description, a mere waist-cloth being at times the only garment used. As we worked further south, however, towards the Trengganu and Pahang frontiers, this free exposure of the person diminished continually, until in Trengganu town we found the sarong frequently worn as low as to the ankles, exactly as in most of the States under British protection.

The specimens of dress collected consisted chiefly of sarongs, the most valuable specimens of which (presented to the expedition by the Raja Muda of Patani and the Sultan and Raja Muda of Kelantan) were unfortunately stolen after they had been handed over to the expedition's agent in Penang. In this way some unique specimens were lost. On the other hand, a fairly complete set of named sarong patterns, showing the arrangement of the threads in producing a great many varieties of the Malay check patterns, were obtained, this point being an especially interesting one, as it exhibits in the Malay Peninsula an exact parallel to the existing Scotch (and former Irish) tartans. Among the miscellaneous articles of attire collected may be mentioned a series of head-dresses, shoes, sandals, &c., and some curious sets of toilet requisites carried on the person (including silver tweezers, cane tooth-brush, silver ear-pick, and silver tongue-scraper), and a set of exceedingly ingenious and primitive folding palm-leaf umbrellas, which are constructed on an entirely different principle from those of Europe.

Ornamentation.

Among the Malays of the East Coast and Kedah, as among those of the British possessions, the adornment of personal belongings and house furniture is seldom rich, and is the exception rather than the rule. In certain departments, however, with which Moslem tradition has not

interfered, the Malay artificer shows no marked inferiority to his fellow worker of China or Hindustan. The work of Malay gold and silver smiths in the Peninsula may in fact generally be distinguished from that of their Chinese and Indian *confrères* in the same region by its being less florid and in juster taste than the latter, and finer in execution than that of the former.

This question of ornamentation is of especial interest on the East Coast, where Mohammedanism may be seen struggling for the mastery, and not always getting the better of the spirit of the people. Most important in this connection are the rare traces of anthropomorphic and zoomorphic decoration, *e.g.*, in some of the axe-helves brought back by the expedition, which bear an astonishing likeness to certain Polynesian designs, as well as in the ornithomorphic ornaments, which, like the frigate bird to which Dr. Haddon has drawn attention in neighbouring islands, play so large a part in the East Coast rites of marriage and circumcision. In the case of the latter ceremony the anomaly is especially remarkable, the candidates for circumcision being usually first paraded in a chariot representing some animal or bird, a thing which I have never seen among the West Coast Malays, who are in closer touch with civilisation.

East Coast designs (more especially those of animals) may conveniently be studied in the extensive series of Malay 'fancy' cake-moulds collected from the various districts through which we passed. I regard this series as an important one, the designs being very fairly representative of this branch of Malay decorative work. The objects represented include the lion, elephant, bull, goat, and several kinds of tortoise and fish ; the rose and other flowers ; the axe and various forms of the Malay dagger, or kris. For the same purpose I obtained some fine specimens of mat-work, basket-work, needlework, weaving, photographs of decorative house-walls, pottery stamps, and three beautiful specimens of Kedah water-chatties, one of which is decorated with a floral design, and the other two with representations of fish, which are depicted as swimming round the waist of the chatty.

Weapons.

Among the Malayan daggers the most interesting was perhaps what Professor Louis calls the 'kingfisher' variety of the Malay kris, the hilt of which represents a sitting figure with an abnormally long nose, which in some cases reaches a length of several inches, the body of the figure itself being only about 3 inches high. This particular dagger has a very long scabbard, and is frequently if not usually inserted in the belt in the middle of the wearer's back. To draw it the wearer gives a backward kick, which, just touching the bottom of the scabbard, drives the hilt upwards between the shoulders, where it can be seized by the hand (over the shoulder) and drawn for action.

Hunting and Fishing, &c.

As regards the series of traps, snares, and nets used by Jungle Malays, of which a large collection was made, the greatest ingenuity, as well as a considerable knowledge of the life-history of the animal, is often exhibited in their construction. Magic as a rule plays a large part in the processes employed, and I hope in due course to be able to work out this most interesting side of Malay ethnography.

An ingenious method was investigated of catching male elephants (instead of corralling them) by means of a snare set under a tree to which a decoy (female) elephant was tethered. This method of elephant-catching requires, of course, a cord of immense thickness and strength.

Fire-making and Cooking Implements.

Some interesting specimens of the cocoanut scraper, two representing animals, and one a man prostrating himself in prayer, were obtained at Singora. But perhaps the most interesting objects collected under the above heading from an ethnological point of view were a set of the fire syringes (generally manufactured from bone or horn) which are still used in some up-country villages for the production of fire.

The collection of Malay cake-moulds has already been referred to. Notes were also taken in detail of the methods of making many kinds of Malay 'fancy' cakes and sweetmeats, as well as a number of other dishes. The working out of my collection of notes upon Malay cooking processes has been very kindly undertaken by Miss Duckworth.

Coins, Weights and Measures.

The collection of coins (native 'cash'), weights and measures is representative of all the important local States in which Siamese or Straits money has not yet usurped the place of the native currency, as well as of several in which the native currency has now long become completely obsolete. The collection of coins includes two interesting gold *dinars* from Jambu, in Patani, which are stamped with the figure of a bull, and are probably of local coinage. They have some resemblance to a small gold coin, formerly current in Achin (Sumatra), but are apparently unrepresented in any British collection. This, indeed, appears also to be the case with a large number of the specimens of tin cash. They are cast in the form of trees, which are called cash trees, the three specimens of which, obtained by the expedition, are, I believe, unique in this country. The general type is that of the round cash, with a circular hole in the centre, though one kind, the half-cash of Trengganu, is a solid round coin (without the hole). In some of the designs Javanese affinities may be traced. Mr. H. Grueber and Mr. W. J. Rapson, of the British Museum, have both seen these coins, and Mr. Rapson has most kindly measured and weighed them. They have now, together with the weights and measures, been handed to Professor Ridgeway, who has already done a good deal towards working them out.

Sets of weights and measures were also obtained whenever possible in each of the East Coast States. Some of these are stamped with the stamp of the Raja, a charge for affixing which is made in several of the States. The Malay 'gantang' roughly corresponds to our own gallon measure. The 'chupak' represents the half cocoanut shell (of which it usually consists), and this again is further subdivided.

Another valuable set from an ethnological point of view is that of the primitive weighing machines in the shape of ungraduated steel-yards which are used for weighing out fixed quantities of certain recognised substances, *e.g.*, salt, 'blachan' (the well-known strong-smelling Malay 'prawn paste'), cotton, and tobacco. For weighing rice a much larger variety is used, which may be made adjustable under certain circumstances.

Trade.

A great many statistics were obtained, in passing, about trade, the figures of imports and exports being obtained for five out of the seven States which go to make up the old Malay country of Patani. In some cases these figures were those for the first year in which the statistics had been properly kept, a Siamese clerk having been appointed to do the work on the previous first of April (the New Year's Day of the Siamese). These statistics, therefore, may be taken as fairly reliable, and as showing the character of the trade and the stage of development of the people.

Agriculture.

A quantity of notes were collected about agriculture. Swamp-rice (on the embankment system) and hill-rice were both grown as in the West Coast States, the latter especially in 'jungly' places.

In most parts of the Peninsula the Malays do not habitually use the sickle, but those who do use it generally prefer to have it furnished with teeth. Specimens of this instrument were obtained, as well as of an ingenious variety which has a long wooden crook springing from the base of the handle for drawing together the heads of rice before they are cut with the blade. The habitual Malay (Peninsula) reaping knife consists of a blade set in a horizontal piece of wood which is affixed transversely to a short bamboo stick. The rice is often roughly threshed by striking the heads of grain against the rungs of a short ladder of about three feet in length, which is made to lean against the inside edge of a large tub, but occasionally it is laid upon mats and trodden out by buffaloes, or in smaller quantities by foot. I may add that buffaloes are similarly used for breaking up the surface of the ground before the rice is planted.

Metal-work—General.

As regards Malay metal-work, Mr. W. Rosenhain (late of the Engineering Department of Cambridge University) last year read a paper before the Association, and more recently before the Institute, in which he touched upon various points of Malay metallurgy in which his experience was likely to prove useful. His investigations covered a portion of my notes upon Malay kris-making, copper founding, chain making, and goldsmith's work.

Ironwork.

A series of specimens illustrating the Malay method of manufacturing a waved and damascened 'kris' were collected at Trengganu, together with detailed notes of the operation extending over three days, and photographs of the blacksmiths at work in the forge. To produce the damask a 'pile' is made consisting of layers of iron: this is welded into a rod, and heated and twisted into the shape required for the design of the damask (usually some kind of a scroll). The scroll is laid between other layers and welded until the edges of the welds of the scroll appear through the later layers. The 'waves' are produced by heating the entire blade and then cooling it with water throughout except at the point where a 'wave' is required. This portion being still red-hot gives way on being hammered, and a repetition of the process with the blade reversed makes a single complete 'wave.' The Malay smith uses tool-iron, and seldom if ever smelts himself; but in one place I was shown what I believe to have been telluric iron cropping out above the surface of the ground, and which I

was assured was formerly manufactured into kitchen utensils, though unfortunately the smith had long left the neighbourhood, and I could get no further information about it. The Malay smith makes all sorts of weapons (chiefly daggers and knives) as well as agricultural implements (axes and hoes).

Copper-work.

The manufacture of copper vessels which I witnessed in Kelantan and other places is effected by the *cire-perdue* process, of which my notes contain full details. Photographs were taken at various stages of the operation, and the specimens include copper vessels in all stages, from the making of the mould to the finished article, as well as specimens of tools used by the operator. An alloy of tin, which is called by the Malays 'white copper'[1] (for which it may be merely an inferior trade substitute, in which case the name may be a mere tradition of *tutaneg*, or 'tooth-and-egg' metal, as it is sometimes called in the trade), is cast by an almost identical (*cire-perdue*) process.

Tin-work.

The trade of the tinsmith (which consists largely in the making of tin oil lamps) is almost exclusively in Chinese hands, but certain branches of it form special industries. Thus the casting of chains to serve as weights for casting nets is a Malay industry, and is effected by means of a very ingenious mould, which after casting a first series of links can be taken to pieces and reversed so as to enable a second row to be cast through the first, the combined series thus forming a chain.[2] Another very important allied industry consists of the manufacture of the tin coins or 'cash,' of which every petty State on the East Coast once had its own type, but which are fast becoming obsolete in most localities. A very interesting and important point (referred to above) about the manufacture of these 'cash' is that they are cast in the shape of trees, which are called 'cash trees,' three specimens of which I was fortunate in obtaining; a fact which may possibly give fresh meaning to the 'shaking of the pagoda-tree,' which was formerly so familiar a phrase with Englishmen.

Gold and Silver Smith.

A set of goldsmith's tools, goldsmith's balance and weights, goldsmith's crucible, and other articles used in his work were obtained for the expedition, making a very interesting series. An excellent photograph of the goldsmith at work, showing his small portable furnace and bellows, was also taken, and details of the methods ascertained which in this case at all events are clearly of Indian origin. The most interesting process (of which full notes were taken) was perhaps that of reddening the gold, which is effected by artificial means, and gives it a greatly enhanced value in the eyes of Malay buyers.

Carpentry (Houses and Boats).

Photographs and notes were taken of the building of houses and of boats. The information collected under this latter head is being incorporated in a monograph upon the boats of the Malay Peninsula by Mr. H. Warington Smyth, the material being based upon my notes and the large collection of Malay boats and boat-building models now in the Cambridge University Museum.

[1] White metal. [2] Used to weight casting nets.

Sheath-making (Cabinet-work).

The making of sheaths and hilts (for knives and daggers) is a separate industry about which full details were obtained, together with a complete set of sheathmaker's tools, including some very ingenious gauges for measuring the depth of the hollow in a sheath.

Pottery.

I saw in several places the making of the unburnt article. A portion of clay is separated from the heap, moistened, and kneaded partly by foot and partly by hand. When sufficiently worked up it is 'thrown' on the wheel, *i.e.*, it is placed upon the centre of the potter's wheel, which is a species of small turn-table resting on a finely polished hard-wood pedestal or block upon which it revolves, the lump of clay in the centre being moulded by hand as it revolves with the wheel. With considerable difficulty, owing to its being thought an unlucky object to sell, I succeeded in buying one of these wheels as a specimen, together with the half-formed vessel then standing upon it. When the shaping process is complete the pots are decorated (the design being partly printed by means of the stamps and partly traced according to requirements with a small spatula or pointed stick), after which they are fired and piled in stacks in the open until the time comes for their removal. Glaze is not used, but I have seen pots being painted with a species of dark-red stain or 'paint,' as the Malays call it (made by grinding a kind of laterite and mixing it with water, when it is applied to the vessel 'by way of ornament,' as the Malays say.

Rope and String Making.

A great deal of rope and string was being made at Trengganu, much more than in any other place visited by the expedition. Exhaustive lists of the substances of which the raw material was composed were made in more than one locality, the processes investigated, and several kinds of apparatus used for the twisting of the strands, one of them a species of box with pins revolving in opposite directions, were purchased.

Mat and Basket Work.

A large number of mats and baskets were obtained by the expedition, but it has not yet been possible to do anything towards working them out, though Mr. H. Ling Roth has kindly offered to undertake the former. The mats which were made by the women were usually composed of woven strips of *mengkuang* (screw-palm) or pandanus leaf, the latter producing the finer article, but various other vegetable substances were used. For the mat-work wall-screens of a house flattened stems of bamboo were combined to form many striking patterns, whilst for the wall screens of a rice barn the flattened stem of a creeper was used. Mat-work was also largely used for sails. When the strands, which are made by slitting up the leaves into strips with a toothed instrument, are dry enough, the operator, sitting on the floor of her house, presses down the even strands with her foot or a ruler-like implement constructed for the purpose, at the same time lifting up the odd strands under which she proceeds to push the even ones with a species of wooden bodkin. Many of the sleeping mats [illegible] those on the Aring River) were of beautiful workman- [illegible] ready market in the East Coast States. Baskets are

made of bamboo, cane, and many other vegetable substances, and though they are as a rule made plain are not unfrequently (especially when used for holding rice) decorated with tasteful patterns.

Spinning and Weaving.

The set of apparatus used for spinning and weaving forms one of the most valuable series brought back by the expedition. The spinning industry is already as nearly as possible obsolete, being only practised by the poorest of the poor in out-of-the-way jungle districts, and the implements when seen had to be purchased at sight for whatever their owners would accept in payment, as there was but small chance of meeting with them again. The cotton is first passed through a small hand-mill or gin (of which two specimens were obtained) for the removal of the hard black seeds. It is then scutched by means of a small bow (one specimen purchased), the string of which was twanged with a short piece of bamboo (also purchased), flattened, and rolled a little on a special board with a specially made rolling-pin (both purchased), spun off on the point of a spinning-wheel of the Indian (Behar) type, and wound off on to a winder (purchased), stretched on a rack (purchased), dipped and brushed with the fruit of the nipah-palm (brushes purchased), dyed and transferred to the spools which were hung on a spool-carrier (also purchased). So far as the spinning goes there does not seem to have been any important divergence from Indian methods. The warp-laying, however, appears to be done on a system for which I have as yet failed to find any parallel. In India (Dacca) two parallel rows or rods about four feet apart are planted in the ground, and the warp-layer, holding a small wheel of warp yarn in each hand, passes the latter over one of the parts, and then walks along the rows laying down the threads and crossing them. In parts of Sumatra this method may, I believe, be seen, but the Malay warp-layer of the Peninsula, on the other hand, arranges the spools in an elongated frame, which may be compared to a ladder, of which the spools form the steps or rungs. This frame or spool-ladder is suspended horizontally from the roof-timbers of the house, and on the floor beneath it is deposited a second frame, which consists of a number of long pegs (probably corresponding to the rods used by the Indian method), which are fitted firmly into a couple of boards, the distance between which may be varied by shifting a central board which runs between them. Round the pegs just referred to the warp-threads are laid, the threads being drawn down as required from the spools lying in the frame above the warp-layer's head. It will be interesting to discover a parallel to this process, which is, I believe, widely known among Malayan tribes.

The Malay shuttle again presents a marked divergence from the Indian type, though the methods of pattern making (by tying and dyeing the threads, &c.) appear to be similar to Indian methods, and are identical with those followed in other parts of the Malay region, *e.g.*, in Borneo and Sumatra. Throughout the Siamese-Malay States I collected specimens illustrating the various stages in the process of dyeing, to show the arrangement of the threads in the formation of the favourite Malay check-patterns. In order to complete the series I purchased a Malay loom, with the cloth in process of making, which is now with the rest of the ethnographical specimens brought back by the expedition. The specimens also include embroidery and needlework frames.

Miscellaneous Industries.

Other interesting industrial specimens which were obtained were (1) the grooved hard-wood block on which waxed cloths are polished by means of a cowry shell, the pressure being applied by a springy rod, the upper end of which is made fast to one of the roof timbers (cowry shell, rod, and cloth also purchased, and photograph taken of operator), to which may be added (2) an oil-press for manufacture of cocoanut oil. (3) Model of a sugar-cane press, worked on an ingenious elaboration of the cog-principle. (4) A tobacco-cutting machine. The tobacco leaf is pushed along a species of shallow trough till it reaches a hole (at the end of the trough), and is then sliced off with a sharp knife as it is pushed through the hole.

Of non-industrial specimens I may specially mention the sets of Malay fighting-cock spurs and the series of Malay instruments of music, including Malay fiddles, flutes, and the primitive instruments made of bamboo which are found everywhere among Jungle Malays. I may here, too, mention the phonographic records (so kindly undertaken by Dr. Lloyd), most of which were records of the songs of the aborigines, though a few were those of Jungle Malays.

Prisons and Instruments of Torture.

The system of confining prisoners in small cages or kennels about 6 feet by 2 feet by 6 feet is rapidly becoming obsolete, but still lingers on in a few localities. We brought away with us most of the typical furniture of a Malay lock-up, including the huge bamboo yoke, or 'cangue,' which the prisoner wears round his neck on his way to jail, and which consists of a couple of big bamboos about 10 feet in length fastened together with pins. In addition to the cangue were obtained (1) a small beam which served as the local 'stocks'; (2) apparatus for compressing (crushing) the thumb or great toe; (3) apparatus for compressing (crushing) the temples, a species of big nutcrackers the application of which to the victim's skull is said to have been frequently fatal; (4) apparatus for strangling condemned criminals. (5) Photographs were also taken of two men who had their hands and feet lopped off for theft, as well as of a number of prisoners who were confined in the kennels above referred to.

Ceremonial Rites and Games.

A number of objects obtained by the expedition were connected with ceremonial rites, especially marriage and circumcision, about both of which ceremonies a large body of information was obtained.

Games were also carefully studied, full descriptions of many of them being taken down as they were performed.

Popular Religion and Folklore.

A large number of the specimens and notes collected fall under this heading, and these it is my intention to compare with the contents of my book on Malay magic as soon as the opportunity offers. The notes taken may be classified as follows :—

(1) Folk-tales and fables.
(2) Specimens and notes relating to popular religion and magic.
(3) General mythology and superstitions.

Of the foregoing (1) a small selection of the best fables and folk-tales has been made, and will now shortly appear, under the auspices of the University Press. It is entitled 'Fables and Folk-tales from an Eastern Forest.' (2) The notes on religious ceremonies include detailed descriptions of the rites connected with marriage, adolescence, and death; annual ceremonies for the expulsion of evil spirits from the villages by means of spirit-boats; invocations of the elephant-spirit, &c.; hunting, fishing, and trapping charms, and ceremonies performed by the medicine-man both for purposes of divination and for the expulsion of evil spirits from sick persons by means of good ones, as well as various spiritualistic performances such as the fish-trap dance, which was witnessed in several places.

Other of my notes describe the expulsion of evil spirits from inanimate objects, *e.g.*, fruit trees and crops, as well as various methods of working upon nature by means of 'make-believe,' *e.g.*, by the ceremony of taking the rice-soul, by ceremonies for the production and prevention of wind and rain, &c.

This latter class includes a great many notes on superstitions about natural phenomena, birds, beasts, &c., which will be valuable for purposes of comparison with the beliefs held by the West Coast Malays.

Aborigines.

In order to deal with my notes upon the wild aborigines, I have planned the outlines of a book, which I hope to publish at no very distant date, in which they will be incorporated together with much of the information previously collected by myself on the same subject as well as that obtained from other writers. The information collected during the expedition consisted of notes on physical characteristics, dress, ornaments, weapons, hunting and fishing, food and cooking, agriculture and arts, music, songs and dances, wedding and funeral ceremonies, medicinal and other notes, mythology and superstitions, magic and religion, vocabularies and language, and a variety of similar subjects.

A chapter on the measurements taken and the physical characteristics of the aborigines is being worked up by Messrs. W. L. H. Duckworth and Laidlaw. The phonographic records of their songs have been sent to Dr. R. J. Lloyd, of Liverpool, the well-known phonetician, who has already commenced work upon them. The vocabularies and grammatical notes (the former consisting, I believe, of several thousand words) have been sent to Mr. C. O. Blagden, who has kindly undertaken to write the chapter on the language.

Phrams.

As regards the Book of the Phrams, referred to in my last report, I regret to say that I am not yet able to report much progress. The only evidence as yet forthcoming has been of a negative character, though it is nevertheless by no means without importance. The Phram-book has been examined by Dr. Grierson, of the Linguistic Survey of India, who has pronounced it not to be composed in any Indian dialect. What appears to be required for its decipherment is a combined knowledge of Siamese and Sanskrit, or Pali, a combination which has hitherto proved not very easy to encounter.

Silchester Excavation.—Report of the Committee, consisting of Mr. ARTHUR J. EVANS (*Chairman*), Mr. J. L. MYRES (*Secretary*), *and* Mr. E. W. BRABROOK, *appointed to co-operate with the Silchester Excavation Fund Committee in their Excavations.*

THE Committee have to report that the excavations at Silchester in 1900 were begun early in May, and continued, with the usual break during the harvest, until December 4.

The excavations were confined to the large area, containing in all 8 acres, situated between *Insula* XII (excavated in 1894) and *Insula* XXII (excavated in 1899), and extending up to the north gate and town wall. The area in question contains four *insulæ*, which have been numbered XXIII to XXVI.

Insula XXIII formed the northernmost of a series of unusually large squares occupying the central portion of the town. A fair-sized house at the south-west corner was uncovered by the late Rev. J. G. Joyce in 1865; the recent excavations have revealed an additional series of chambers on the north-east. Another house of large size with several mosaic pavements was also uncovered on the east side of the *insula*, and in the mouth of its courtyard was a small square building which may have been devoted to sacred purposes. This had been built up round a small and earlier structure of the same character. The other traces of buildings in this *insula*, despite its size, were singularly scanty, but the rubbish pits and wells were unusually productive in objects of interest. In pottery these yielded upwards of a hundred whole vessels of all kinds and sizes, and from one of the wells was recovered another great hoard of iron tools, mostly a smith's, similar to that found in 1890 in *Insula* I, but considerably larger numerically.

Insula XXIV forms a long and narrow triangular strip, bounded on the north by the town wall and its bank. Such strips have hitherto proved more or less empty of buildings, but in this case it contained two houses, one of which was of large size and of exceptional interest from the peculiarity of its plan and the number of mosaic floors in it.

Insula XXV, a small triangular area next the north gate, contained only two small structures, apparently connected with dyeworks.

Insula XXVI, though of some size, had in it at least two houses: a small one on the west, and another in the south-east quarter which was partially uncovered by Mr. Joyce in 1866. Its complete plan has now been revealed. There are also traces of a ruined house near the south-west angle. Besides the houses, *Insula* XXVI contained traces of at least three other structures. One of them was represented by a solid circular platform with a cement floor 27 feet in diameter, enclosed apparently by woodwork or half-timbering. The pit and wells in this *insula* were few in number, and yielded few objects of interest.

Taken as a whole, the results of the season's work were fully up to the average, both in the character of the buildings uncovered and the variety and number of objects found in and about them. The quantity of pottery and the hoard of smith's tools are also quite exceptional. The objects in bronze, bone, &c. also include many interesting things.

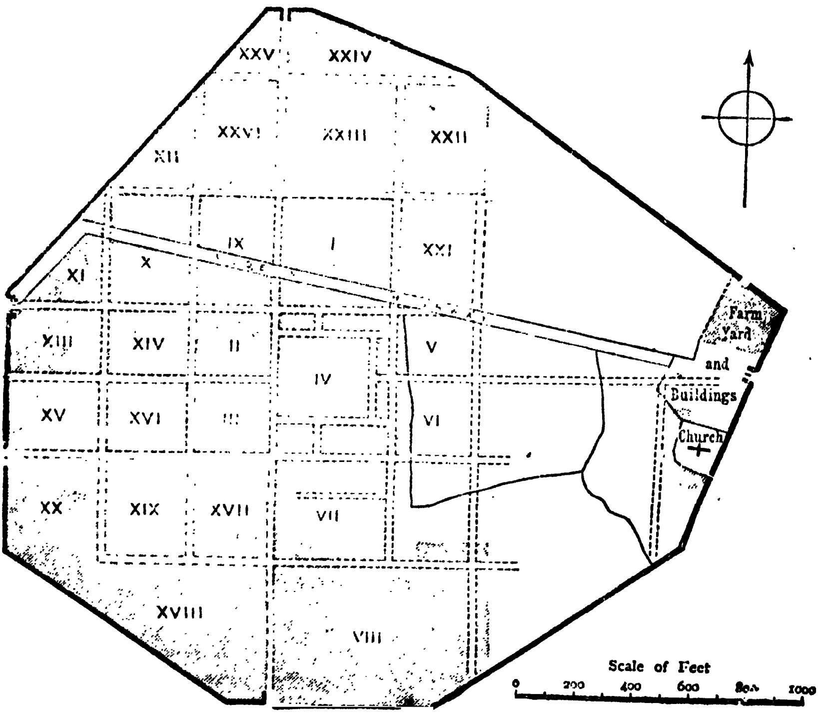
The coins found were as numerous as usual, but not very important.

A detailed account of all the discoveries was laid before the Society of Antiquaries on May 23, 1901, and will be published in 'Archæologia.'

A special exhibition of the antiquities, &c., found was held, as in former years, at Burlington House by kind permission of the Society of Antiquaries.

The statement of accounts for the year 1900 shows a total expenditure of 557*l.* 3*s.* 7*d.*

It is proposed, during the current year, to excavate a strip of ground east of *Insulæ* XXI and XXII, and, if possible, to begin the systematic exploration of the grass field in the centre of the town. The Committee therefore ask to be reappointed, with a further grant.



Anthropological Photographs.—Interim Report of the Committee, consisting of Mr. C. H. READ (*Chairman*), Mr. J. L. MYRES (*Secretary*), Mr. H. BALFOUR, Professor FLINDERS PETRIE, Dr. J. G. GARSON, Mr. E. S. HARTLAND, *and* Mr. H. LING ROTH, *appointed for the Collection, Preservation, and Systematic Registration of Photographs of Anthropological Interest.*

THE Committee report that further progress has been made in the collection and registration of photographs of anthropological interest, and that a first list of photographs is in course of preparation. The Committee ask to be reappointed, with the balance in hand from the former grant of 10*l.*

The Age of Stone Circles.—Report of the Committee, consisting of Dr. J. G. GARSON (*Chairman*), Mr. H. BALFOUR (*Secretary*), Sir JOHN EVANS, Mr. C. H. READ, Professor R. MELDOLA, Mr. A. J. EVANS, Dr. R. MUNRO, Professor BOYD DAWKINS, *and* Mr. A. L. LEWIS, *appointed to conduct Explorations with the object of Ascertaining the Age of Stone Circles.* (*Drawn up by the Chairman.*)

THE Committee have to report that after careful consideration of the various stone circles in different parts of the country that of Arbor Low in Derbyshire was fixed upon as the most convenient and suitable for the exploration which the grant at their disposal would permit of being undertaken, a well marked ditch and rampart surrounding it, while the circle itself is fairly complete as regards the stones forming it, although none of these are now standing. The consent of the ground landlord, the Duke of Rutland, was freely given for the exploration, as was also that of the First Commissioner of Works, under whose care the circle is placed as an ancient monument under the Act of Parliament. The tenant of the farm, Mr. Warrilow, likewise readily acquiesced in the project. The Committee were fortunate enough with the consent of the chairman and committee of the Taunton Museum to secure the services of Mr. H. St. George Gray, the curator of that museum, who has had much experience, acquired under the late General Pitt-Rivers, to direct the exploration. Finally, through the kindness of Mr. A. Pitt-Rivers, the excellent apparatus used by his father in his excavations was placed at their disposal. To one and all of these gentlemen the best thanks of the Committee are due for the part they have taken in facilitating the examination of this important and interesting monument of antiquity.

The following is the report submitted to the Committee by Mr. Gray which gives an account of the work conducted by him, after which follow reports by Mr. H. Balfour on the stone implements found, and by Dr. Garson on the human remains.

On the Excavations at Arbor Low, August 1901.
By H. ST. GEORGE GRAY.

Arbor Low is situated in one of the most sparsely inhabited districts of Derbyshire, in the parish of Bakewell, from which town it is 4¾ miles distant in a south-westerly direction as the crow flies. The nearest railway station is Parsley Hay, one mile to the west, on the new Buxton and Ashbourne Railway. Hartington is 2¾ miles to the S.W. of Arbor Low, Middleton 2¼ miles to the east, and Monyash 2 miles to the north. The monument, which is situated on a long ridge of hill nearly 1,200 feet above the sea-level, commands a most extensive view towards Buxton and Bakewell, in a northerly and easterly direction.

Preliminary arrangements having been made and the workmen having been directed to remove turf in various places, the first thing to do was to begin a complete survey of the monument. A square (98 metres = 320 feet on each side) was formed round the vallum, enclosing an area of about 2⅓ acres, and the plan of the stones was commenced at a scale of

240 to 1 (=20 feet to an inch). The exact position of each stone was taken by means of bearings and triangulation from fixed points, checked by cross-measurements. The plateau on which the megaliths lie is encompassed by a fosse, and averages about 49 metres in diameter. The figure formed by the *circle* of stones is pear-shaped, the top of the pear to the south-east, the point to the north-west. It consists of rough unhewn stone slabs of mountain limestone, of which many of the largest average 3 metres in length by $1^{m}\cdot40$ in breadth: they are of variable thickness, extremely irregular in form, and some are fractured; they all, with one exception, lie upon the ground, many in a somewhat oblique position, all more or less recumbent. The weathering of their surfaces, the cleavage, the 'pot-holes' in them, are intensely interesting, especially to the geologist. In giving numbers to the stones (Nos. I. to XLVI., in the plan) there is no pretension made to count the original number of the stones as put into position by the constructors of the monument; they are simply numbered to facilitate reference and to distinguish one from another in describing them. Some of the very small stones and stumps have been numbered separately (Nos. 1 to 13). The position and slope of the stones individually are extremely varied: the majority lie in shallow depressions, although some are quite on a level with the general turf line; others, again, are surrounded by slight mounds, the turf in many cases growing round and over the sides of the stones. The longest stone is in the centre of the circle (No. II.), which measures $4^{m}\cdot57$ in length, whilst the widest is also in the centre (No. I.), $2^{m}\cdot44$ in width. The largest stone in the *circle* is No. X., the length of which is $3^{m}\cdot96$, and the width $1^{m}\cdot83$. There is one exception to the stones being recumbent, and that is No. XVI., on the west side, which leans towards the north-east at about 35° or 40° with the surface of the surrounding turf: it stands at its highest part $1^{m}\cdot06$ from the ground. It would be desirable to excavate round some of the stones of the circle to endeavour to find holes in which these monoliths may have originally stood. This kind of thing has been done in the exploration of circles on Dartmoor. Dr. Pegge mentions an old man who saw some of the stones standing,[1] and Mr. Bateman another.[2] Glover, in his 'History of the County of Derby,[3] mentions a third, and tersely adds that 'this secondary kind of evidence does not seem entitled to much credit.'

The published plans of Arbor Low are for the most part far from correct, Sir J. G. Wilkinson's plan being the only exception.[4] In this small plan the position of the circle of stones is fairly correct, although there are several discrepancies in the proportional sizes of the stones, and the central group should be a few feet further north-west and west.

The area, or plateau, enclosed by the fosse presents a very uneven surface, but the contours across this part of the plan have been delineated to follow the general slope of the ground, and not to mark every little depression or slight elevation as it occurred. The contours, of 0·5 foot (15 cm.) vertical height, show the shape of the monument and its immediate surroundings within the 'square.' The highest contour comes on the top of the tumulus on the south-east rampart (opened by Bateman), the lowest, at the northern corner of the survey, showing a fall of $7^{m}\cdot47$ in the ground from top to lowest part. It is not unusual to take

[1] *Archæologia*, vol. vii. pp. 131–148.
[2] *Journ. Brit. Arch. Assoc.*, vol. xvi. p. 116.
[3] Published in 1829, vol. i. p. 275. [4] *Journ. Brit. Arch. Assoc.*, vol. xvi. pl. 9.

levels on fixed lines giving contours of 1 or 2 feet (30·5 or 61 cm.) vertical height, and to fill in intermediate 15·2 cm. (6-inch) contours by the eye; but to ensure absolute precision, to show the little knolls and depressions on the vallum at the south-west, north, and east, to mark the irregularities made by Bateman on the summit of the tumulus, to indicate the little dyke running in a southerly direction from the vallum—it was desirable that all the 6-inch contours should be surveyed severally, which entailed the necessity of taking some eighteen hundred levels!

The periphery of the crest of the vallum constitutes almost a true circle, with a diameter of exactly $76^{m}·25$, as shown by the outer circle described on the plan. The centre of this circle comes near the middle of the south-western side of stone, No. III. of the central group. The crest of the vallum deviates very slightly in any part from the true circle excepting on the north-west, where it bulges out. The bottom of the fosse, as seen on the surface of the silting, declines from the line of the true circle far more than the rampart, as shown by the inner circle described on the plan, with a diameter of 58 metres; the only segment of this circle that can be said to be true is on the south, south-west, and west. The ditch is thrown out far more than the rampart to the north and north-west; but it would not be expected to find that the fosse silted up regularly and symmetrically all round, whereas the crest of the rampart, of course, is much about in the same position as it was at the age of construction.

The ditch was marked by a depression from the original surface all round averaging $1^{m}·37$, and it is surprising that in the course of all these ages it should not have silted up to a greater extent; had the monument been situated in a chalk district, the ditch would probably have been indicated by a much shallower depression on the surface.

The average height of the vallum above the general surrounding turf-level is $1^{m}·83$ (6 feet)—Dr. Brushfield states 16 feet, *i.e.*, $4^{m}·88$.[1] Judging from those portions of the ditch already excavated, the material obtained from the fosse when it was first excavated was not enough to form the vallum, but the construction of the latter will be mentioned later on when dealing with the excavations. The confines of the rampart are bounded at various points by ten small Governmental stones. The fosse and vallum are interrupted on the north-west and south-east by the entrance causeways, which are not in line with the central group of stones. The causeways are on the same general level as the area occupied by the megaliths and the surrounding land. The circumference of the rampart, including the entrances, is about 246 metres.

The vallum is joined on the south-west by a slightly raised bank—about 30 cm. in height—and an almost imperceptible ditch, which runs for some distance in a southerly direction. It would be desirable to cut a section or two across this so-called 'serpent,' to ascertain if it is of the same date of construction as Arbor Low itself, or more recent.

On the south-east, adjoining the external face of the vallum and partly resting on it, a tumulus stands, the summit some $2^{m}·13$ above the surrounding turf level. 'Between 1770 and 1824 three unsuccessful attempts had been made to discover an interment, but a fourth, made by Mr. T. Bateman on May 23, 1845, resulted in its discovery. About 46 cm. above the natural soil a large slab, $1^{m}·52$ broad by 91·5 cm. wide,

[1] *Journ. Brit. Arch. Assoc.*, 1900, p. 129.

was found to be the cover to a six-sided cist, constructed of ten pieces of limestone of different sizes placed on end, and having a floor formed of three other pieces, these, like the rest, being untooled. No soil had penetrated the cist, and its original contents had been undisturbed. These consisted of two small urns (one 11·4 cm. and the other 12 cm. high), calcined human bones, a bone pin, a small flint weapon, and a piece of iron pyrites.'[1] Mr. Bateman never took the trouble to fill in his excavation properly, the result being that five little knolls exist round the top of the tumulus bounding a rather deep depression in the centre. In addition to this he threw some of his rubbish into the ditch, as indicated by the contours on the plain. The formation of this tumulus, which is probably of somewhat later date than the vallum, has caused a gap to occur in the vallum on either side of the mound. There is also another irregularity in the form of the rampart to the north of the tumulus, caused by a kind of spur which extends half-way across the fosse.

The photographs of the diggings on the whole are not quite satisfactory, although some of them could not well have been better under the circumstances, unfavourable weather prevailing at least for one-third of the time. The photographs of some of the 'finds,' the skeleton, and skull portray the originals excellently.

Excavations.—The excavations were commenced on August 8, 1901, by making a cutting through the ditch, $3^{m}\cdot66$ wide, close up to the south-eastern causeway (called Section 1). Roman remains were looked for under the turf, but without success. The silting was re-excavated 30 cm. at a time as far as practicable. Strewn on the limestone floor of the ditch thirteen teeth of ox were found, and on the bottom in the north-west corner of the cutting, at a depth of $1^{m}\cdot65$ from the surface (2 on plan and section), pieces of red deer's antler—one piece 38 cm. long—were found resting on a solid vein of clay (running between the limestone), which traversed the bottom of the ditch obliquely and continued both ways in south-easterly and north-westerly directions. It appears probable that this may have been used as a kind of pick for loosening the previously fractured limestone at the time the ditch was first excavated, in the same manner as the antlers of the Stone Age described by Canon Greenwell in Grimes Graves.[2] Fifteen fragments of antlers of red deer were found by General Pitt Rivers at the bottom of the ditch of Wor Barrow, Handley Down, Dorset, amongst Stone Age relics.[3] Nothing else was found in Section 1, which was the deepest part of the fosse re excavated; greatest depth $1^{m}\cdot65$. The filling consisted of turf and turf mould, 15 cm.; mould mixed with small pieces of chert, 46 cm. followed by a stiff clayey mould to the bottom. The nature of this latter is well shown by the pick-marks in the photograph. The hard stone sides of the ditch and causeway were exposed.

Sections 2 and 3 were next commenced. Section 3 was a cutting, $3^{m}\cdot05$ wide, made across the ditch, midway between Section 1 and the north-west causeway. The silting was very soon removed in this case, the uneven limestone floor being found at a maximum depth of 55 cm. and a minimum depth of 33 cm. from the surface of the silting. The vallum at this point was particularly high. Three stone implements were

[1] From Dr. Brushfield's paper, *Journ. Brit. Arch. Assoc.*, vol. vi., new series, 1900, p. 134.

[2] *Journ. Ethnological Society*, vol. ii. p. 426.

[3] *Excavations in Cranborne Chase*, vol. iv. p. 133.

found in this cutting. At '3' on plan and section, at a depth of 36 cm. a rudely chipped pointed stone implement (?spear-head), having a plano-convex cross-section, length 61 mm., greatest width 44 mm.; at '6' a worked flake of black flint with fine secondary chipping at a depth of 15 cm; and at '7,' at the same depth, a chipped end-scraper of greyish flint: this implement is of the long narrow variety, with a notch on both sides. At Section 2, about $4^{m}\cdot88$ to the west of the north-western causeway, another cutting, $3^{m}\cdot05$ wide, was made through the ditch and the rampart. The vallum was chosen at this point, as it presented an even surface, and being comparatively low and narrow it would not entail so much labour in removing. No relics were found in this cutting, except a small doubtfully artificial stone scraper picked up on the 'old surface line' (4 on plan and section). The absence of relics in this section was very disappointing.[1] The cutting, however, was of value in showing the material out of which the vallum was constructed and has been plotted in section, on the scale, of 60 to 1. Measuring from the crest of the rampart downwards, the soils, &c., occurred as follows:—(1) Turf and turf mould, 15 cm.; (2) rough pieces of thin-bedded limestone mixed with a little mould, 98 cm.; (3) band of small pieces of chert with a little mould, 9 cm.; (4) yellowish-brown clayey mould, 15 cm; (5) 'old surface line' of dark brown mould, 9 cm.; (6) light-yellowish brown sand. The greatest depth of the ditch in this section was 76 cm., and it was filled to the bottom, below the turf mould, with mould mixed with small pieces of chert. This part of the ditch having been laid bare, the re-excavation of the ditch was continued from this point in the direction of the north-west causeway, the hard stone sides of which were found. As stone relics were more numerous here, and the bottom of the ditch was far more irregular than in Sections 1 and 3, surveys were made in various directions, and have been plotted to a scale of 60 to 1. The average depth of the ditch here was 91·5 cm. from the surface, and the nature of the filling was the same as in Section 1. The following is a list of the finds in this part, called 'Ditch Extension, Section 2.' The numbers tally with those on the plan and in sections.

5. Small flint flake, with fine secondary chipping; depth 21 cm.

8. Stone scraper, with bevelled edge, 36 mm. in width; depth 36 cm.

10. Outside flake of flint, with secondary chipping in two places; depth 24 cm.

11. Flint, chipped along the edge; depth 24 cm.

12. Two pieces of chert, with secondary chipping (?); depth 43 cm.

13. Flint flake, with serrated edge; depth 46 cm.

14. Small narrow scraper of flint, worked all round edges; depth 43 cm.

15. Large flint scraper, of pale bluish-grey colour, with chipped bevelled semicircular edge and pointed end; plano-convex cross-section; depth 70 cm., near the bottom of the ditch.

17. Six flakes of white flint, mostly of exceptionally large size, found together, in the ditch at a depth of 82 cm. from the surface, on a ledge

[1] General Pitt-Rivers once cut four sections, 10 feet wide, through the rampart and ditch of a Bronze Age encampment without finding a relic worth mentioning; but he did not despair, and forthwith commenced to dig away the rampart and ditch all round, being rewarded by finding bronze implements and much pottery.

on solid side of causeway in the north-east corner of the ditch extension, Section 2. These flakes must have been placed on the ledge and forgotten, eventually becoming buried in the silting.

Just to the west of this ledge a small oval-shaped hole in the limestone floor of the ditch was found, filled with a stiff clayey mould, but no relics were found in it. Other doubtfully artificial pieces of flint and chert were found in this excavation, some of which need to be examined by the geologist as well as the archæologist: they have been preserved. The only animal remain found here was a tooth of sheep; depth at 21 cm.

The excavations made in the fosse revealed nothing but early Neolithic chipped stone implements, the majority of which were found below the 30 cm. level from the surface. It would be, however, somewhat rash to state on these grounds alone that the ditch was undoubtedly of Stone Age construction, although the evidence certainly points in that direction, for only a comparatively small portion of the whole fosse at Arbor Low has been explored; in fact, only one-twelfth part. It would be safe to assign the construction of Arbor Low to a definite age, if, say, one-fourth part of the fosse were re-excavated; and the somewhat inconclusive nature of the evidence at present seems to point to the desirability of further excavations being made in the most systematic and skilled manner possible.

Before leaving the ditch it should be stated that its average width at the parts already excavated is $6^{m}\cdot40$, and the average depth of re-excavated ditch beneath surface of silting, $1^{m}\cdot98$.

The remainder of the time and funds were expended in trenching down to the undisturbed rock in the centre of the circle, between the two large stones, Nos. I. and II., and further in an easterly direction. The area excavated, which covered a very irregular surface, measured $10^{m}\cdot67$ by $2^{m}\cdot12$, and is marked on the contoured plan. To the west a stump (No. 13) was found under the turf standing in a leaning position towards the north-east. At '19,' the only fragment of pottery was found at a depth of 15 cm., just under the turf: it consisted of a fragment of rim of Romano-British pottery, grey on the outside and brick-red on the inside. Close to and between Stones I. and II. (20 on plan), a small chipped flint implement—length 33 mm., width 28 mm.—approaching a leaf-shaped arrowhead in form, was found at a depth of 27 cm.: it has a bi-convex cross-section.

The primary idea in making this excavation was to see whether holes could be found in which Stones I. and II. originally stood; but no holes were found between these stones; in fact, the undisturbed ground in this part was struck at about 52 cm. from the surface. To the east of Stones III. and IV. there were signs on the surface of this part having been excavated before (in somewhat recent times). The rock was reached here at very variable depths, and at the extreme east an excavation $2^{m}\cdot40$ deep was made before the undisturbed ground was struck. The hole was filled with rich mould mixed with a little chert. No relics were found, except a fragment of human ulna (9 on plan) at a depth of 15 cm. It is possible that a skeleton or skeletons may have been removed from here, and that this ulna was lost in the filling in. If this part had been excavated before there were no signs of the ground having been disturbed to the west of the small stone, No. IV. Here, close to Stone III., a human skeleton was discovered; the middle of his body (a fully adult male) was situated $1^{m}\cdot83$ to the south-east of the *centre* of the

circle. It was discovered on August 16, but as Mr. Henry Balfour was expected to visit the diggings next morning,[1] the men were directed to cover it up. Next morning the skeleton was uncovered and cleared in order that it might be photographed *in situ*. It was an extended interment, the skull being at a depth of only 36 cm. from the surface. The skull, which was much crushed and weathered, was found on removal to be in forty to fifty pieces; some of the facial portions and sides had unfortunately decayed, so that its restoration could not be made quite complete; the lower jaw was not present. Other parts of the skeleton were missing, including the condyles of the femora, the tibiæ and fibulæ, one patella, the feet, and hands. The end of the left femur came close to the south-east corner of Stone No. III. The skeleton, which was buried in pure mould, lay on the back, with the face turned slightly to north east, and was surrounded by large blocks of stone built up on the south, west, and north sides to within a few centimetres of the surface; the ends of all the long bones were much decayed, the head was to the south-south-east; the bearing along vertebral column was $164\frac{1}{2}°$ S.; the length from the top of skull to the lower end of femora was $1^{m}\cdot19$.

The approximate length of the left femur is about 453 mm., which gives a stature (by Rollet's method) of $1^{m}\cdot66$. This is above the average of a Stone Age man, and below that of a Bronze Age man.[2] The skull has been restored as far as possible, and turns out to be mesaticephalic, or medium-headed, with a cephalic index of about 78·0; so that this interment appears to be of later date than the construction of Arbor Low, but how much later it is difficult to say, no relics having been found with the skeleton. Dr. Garson will no doubt make a report on the skull; and as the meatus auditorius is present on both sides, and the basion also, the majority of the usual measurements can be taken.

At $77^{m}\cdot80$ to the east south-east of the centre of the monument is a small tumulus which appears to have been reduced in height owing to agriculture. As this may probably be connected with Arbor Low it has been surveyed to a scale of 120 to 1, with contours of 6 cm. vertical height. A cutting was commenced on the north; but as mould was found to extend down to a depth of $1^{m}\cdot68$ in places, and it promised to be rather a large undertaking when funds were nearly exhausted, the work had to be relinquished, at any rate for the present. One flake was found near the surface.

Dr. Brushfield's opinion, expressed two years ago, as regards the probable age of Arbor Low was that the monument belonged to the Early Neolithic Age. Judging from the nature of the relics already discovered and their positions, there is some reason for referring it to at least some part of the Neolithic period; but the evidence deduced can scarcely be regarded as conclusive, and we can hardly consider the problem as to the date of construction decisively solved as yet. Neither has the original position of the central group of stones been determined. One thing, however, is certain, that Arbor Low has been used as a place of sepulture.

[1] Mr. A. L. Lewis visited the excavations on August 9, and Dr. Garson on August 22.

[2] The secondary interments, Romano-British, in Wor Barrow (Stone Age), Handley Down, Dorset, averaged $1^{m}\cdot651$ in stature.

ARBOR LOW. [*August* 1901.]

Short Descriptions of Stones as numbered on the Plan. NOTE.—*The length and breadth of the Stones can be ascertained from the Plan.*

Stone I.—In centre, nearly flat, broken in two at N.W. end. Slopes a little to W. At E. point it stands 1½ foot from turf. It also stands 1½ foot from turf on W. side, but there is a trench along this side of the stone. Surface fairly smooth. There is a small flat stone to E. (not numbered), which is only about an inch above turf.

Stone II.—Near No. I., nearly flat, but sloping a little towards W. to turf line. It is about 10″ above turf on E. side. The slab is rather thicker at the N. end than at S. end.

Stone III.—To the S.E. of No. II, flat, sloping very slightly to E. Pitted surface. The human skeleton was found close to S E. of this stone; in fact, the left femur almost touched the stone.

Stone IV.—A small stone to N.E. of No. III. Slopes rather considerably towards S.; only about 2″ above turf all round.

Stones V., VI., and VII.—Photographed together from S. In a group, the nearest stones of the circle to the S. causeway. A considerable depression in turf to S. of No. V. At S. end this stone stands about 2 feet above average turf level, and it slopes gradually to turf on N. The under-surface of stone at S. has been much polished by the rubbing of sheep, &c. No. VII. slopes towards N., and is fractured in two places. It is somewhat thicker at N. end than at S., where it is about 1 foot from turf. No. VI. is a fractured stone about 9″ thick, which stands on end between Nos. V. and VII., leaning slightly to W.[1]

Stone VIII.—Lies in a slight depression at about 9″ above level of turf, in depression all round; slightly higher in the middle. Pitted and rough, but 'pits' are not very frequent, large but not deep.

Stump 1.—Between Stones IX. and X. Stands about 1 foot from turf level, and leans a little towards centre.

Stone IX.—Flat, sloping, slightly towards ditch on S.W. Stands 1½ foot from turf on S.W., and 1 foot on N.E. Much pitted surface, small, frequent, and deep.

Stone X.—Photographed from S.E. Marked depression in turf at W. end of stone, which end is squared, or, rather, of oblong form, 2 feet in thickness. This depression sinks to about 6″ below the surrounding turf level. The stone slopes towards the N.E., the stone only showing about 10″ above turf on E. side. The upper surface is fairly flat, and is characterised by a broad crack along middle, and what may be called a 'pot-hole' near N. corner. Turf grows between stone on N.W. Much sheep-rubbed underneath to S.W.

Stones XI., XII., and XIII.—Small stones in a little group between Nos. X. and XIV. In a slight depression, partly in continuation of deep depression at the W. end of Stone X. No. XI. slopes towards centre, and has a smooth flat surface. Height 1 foot from turf at S.W., 4″ at other end. No. XII. has turf growing up all round the sides; greatest height at N.W. is only 4″ from turf. No. XIII. slopes towards S.W. and S.E. to turf; on other sides only 4″ from turf.

Stone XIV.—Lies in slight depression at ditch-end; flat stone, pitted in places by weathering, with cracks in which turf has grown. Height about 10″ from turf all round.

Stone XV.—Very smooth surface, sloping to turf on E.; at W. end, which is square, its height is 1·3 foot from turf.

Stone XVI.—Upper side fairly flat; leans at about 35° or 40° with general turf level towards the N.E. In a well marked depression all round, from which it stands at highest part 3½ feet. Thickness of stone about 1½ foot at S. and about 1½ foot at N. The only stone in the circle that can be said to be standing at the present time.

Stone XVII.—Lies in slight depression; nearly flat, but sloping slightly towards

[1] Mr. Lewis, who measured the circle in May 1871 (see his plan, &c., in *Anthropologia*), says that Stone VI. was not then in its present position, but has been placed there since. On going over the ground in 1901 to revise his plan, he thought he saw signs of a certain amount of surface digging during the previous thirty years, but no material alteration in the circle generally.

the W. ditch, where its height is only 6″ above depression in turf, rising at N. to about 1 foot; very rough surface and sides, a little overgrown with turf.

Stump 2.—Cleaved in two  and partly overgrown with turf; about 10′ above surrounding turf.

Stone XVIII.—Slopes off rather considerably to the W. ditch; at E. its height is about 9″ above turf; at W. about 1½ foot from turf. Flat surface, but much pitted, and turf-covered in one or two places.

Stump 3.—Stands at two highest points 1 foot from turf, with a depression, 4″ from turf, across middle.

Stone XIX.—Lies on a slight mound. Height at S. 0·7 foot from surrounding turf, rising slightly higher (ridge N.E. and S.W. line), and then gradually sloping off to turf level at N. and N.W.

Stone XX.—Slopes all round to turf level from a central point about 1 foot high. It does *not*, however, slope off at W. point.

Stone XXI.—Lies in slight depression, sloping slightly towards ditch. Flat surface and somewhat pitted in places. Height about 1·2 foot from turf all round. Ragged along N.E edge.

Stone XXII.—Flat; slopes rather much towards the ditch; height about 1·3 foot from turf all round. Half-oval weathered hole through side of stone on S.W.

Stone XXIII.—Lies in very slight depression, more particularly marked on the ditch side. Stone has very uneven side towards W. Rough surface, pitted somewhat to S.E., S., and S.W., and highest at these points. Flat surface to N. and N.W., where it stands nearly 1 foot from turf. At other points it averages 1·2 foot in height.

Stone XXIV.—Slopes towards N.; slopes off to turf level at N.W. and N., but not at N.E. Depression in turf at S. end, extending under stone to N. half-way across stone. At S.E. corner its height from turf in depression is 1·3 foot; at S.W. 2 feet from same, gradually sloping along W. face to turf on N.W. Flat surface with very small but numerous 'pittings.'

Stone XXV.—At S. there is a marked depression in turf, but not at the N. Height of stone above depression at S. 2¾ feet. The stone slopes towards the N., where it reaches the turf level. Rough surface, with fracture at N., running N.W. to S.E. Turf rises in depression under the stone at S., to support it. The stone is tilted up at S., at an angle of about 20° with surrounding turf level. Much rubbed underneath at S. by sheep.

Stone XXVI.—In slight depression to N., more marked to S. Slopes towards N., almost to turf level. At S. its height is about 2 feet from depression in the turf, and the stone itself is about 1½ foot thick at this end. Large 'pittings,' but not very numerous. Two oval holes, through stone to turf. The larger hole measures 18″ × 10″ in the line of stone, a little to N. of middle.

Stump 4.—Very narrow and sharp, about 8″ above surrounding turf.

Stone XXVII.—Very rough, standing at middle about 1·5 foot from surrounding turf. At N. there is an angle only 3″ from turf, from which angle the stone rises abruptly to top.

Stone XXVIII.—Height only 2″ above surrounding turf; almost entirely overgrown except a small portion to N. Flat.

Stone XXIX.—Pointed at both ends. Slopes somewhat considerably towards N. Smooth flat surface. A depression in turf at N. only, where it stands about 1 foot from turf in depression. Smooth sides all round. The thickness of stone appears to be only 6″ at N.E. point, whilst on the S.W. side its thickness is 2 feet, to which it gradually rises from N. to N.E. The stone is thicker at S. than at N.N.W.

Stones XXX. and XXXI.—Slight depression in turf between and to the E. of these stones. Both flat and fairly smooth; height only about 1″ or 2″ from turf. No. XXX. slopes very slightly to N.; No. XXXI. slopes somewhat considerably to N. and E.

Stone XXXII.—Of the nature of a stump, but rather larger than those that have been counted as stumps. Slight depression to S.W., and surrounded by a mound of turf to N.E., E., and S.E., where the stone only rises 2″ above turf. On S.W. the top of the stone is 1 foot from turf in depression. Turf grows in places on top of stone, which is rather flat. Rough at sides, sloping abruptly from top at S. and N.W.

Stone XXXIII.—Lies in slight depression, sloping slightly towards ditch.

Fairly flat surface. Height about 1 foot from turf all round. Point to N.E., only 3″ above turf in depression.

Stone XXXIV.—Lies in a marked depression on inner bank of ditch. The depression particularly marked at N. and at E. Stone somewhat heart-shaped and flat and fairly smooth. About 6″ in height above turf in depression all round, with turf growing up sides everywhere, except at W. and S.W.

Stone XXXV.—Flat smooth surface. Slopes slightly towards centre of circle. On W. slopes off to turf. On E. 9″ in height above turf.

Stone XXXVI.—Smooth but uneven surface. Slopes slightly to E., and partly overgrown with turf, especially over centre and to S. and S.S.W. At N. and N.N.W. it stands 3″ above turf, but turf runs up to level of stone on all other sides.

Stone XXXVII.—Lies in slight depression all round, which, however, deepens considerably to E. and S.E. Slopes slightly towards ditch and N., with fairly smooth flat surface. At W. point it is 2 feet above turf in depression, and at E. about 2·3 feet. This stone is cleaving lengthwise, or, rather, horizontally into three slabs. This is particularly well seen on all sides but the N. At N. its height is only 10″ from turf in depression. Upright sides all round.

Stone XXXVIII.—Small flat stone, level with the turf, which is growing over it. Plan shows only that part of stone which appears at surface. Slopes to N. and E.

Stone XXXIX.—On slight elevation. Broken into three pieces, all of which are becoming overgrown with turf. The N. piece is nearly level with turf. The middle has somewhat rounded surface, and rises in middle to about 6″ above turf. The piece to S. slopes from N. end to S., where it reaches the turf; the N. end of this piece is about 7″ or 8″ above surrounding turf.

Stump 7.—Much overgrown with turf. A piece of stone only 9″ × 6″ shows at present, which does not rise above turf level. Plan shows the probable outline when turf is removed.

Stones XL., XLI., and XLII.—Together in a mass in slight depression all round. See photograph. No. XL. slopes to S. and S.S.W. At highest point at N. it is 1½ foot above turf in depression. The S.E. and N.W. points are about 10″ from turf. At S. and S.S.W. it meets the turf. No. XLI. slopes from the S.E., meeting the turf level under No. XLIII.; rather rough, uneven surface, standing at N.E. about 1·5 foot from turf in depression, at S.E. about 1·3 foot, and at S.S.W. about 1 foot. No. XLII. overlaps No. XLI. to S.E., and slightly over No. XL. to N.E.; thickness of stone about 1 foot at S.E; stone slopes to centre, where it is only 4″ from turf. At S.E. end the highest point is about 1½ foot from turf in depression.

Stone XLIII.—Slopes very slightly towards centre of circle. Flat and smooth surface. Runs to turf on N.W., S.E., S., and S.W.; in fact, pretty well all round. At S.E. the stone is about 4″ above turf level.

Stump 8.—Very narrow, just appearing above turf.

Stone XLIV.—Flat, sloping but slightly towards ditch. Height about 7″ from turf level at N.W. S.S.E. corner overgrown with turf, N.E. corner also; in fact, a very little of the stone at S.E. shows above the surface. Uneven, weathered surface.

Stone XLV.—Flat, with very uneven weathered surface and fractured. More than half the stone is overgrown with turf, fairly regularly distributed.

Stone XLVI.—Nearly flat, sloping slightly towards centre of circle. Fairly smooth surface. 'Shoulder' across middle, height 7″ above turf, rising again to 6″ above turf at S. Turf growing across depression below 'shoulder.' Stone almost entirely overgrown, dotted on plan, to S.S.W. of XLVI.

Stumps 9 and 10.—Small stones (not really 'stumps'), just appearing above surface.

Stumps 11 and 12.—Ragged stones, broken off, just appearing above surface.

Stump 13.—This stump, leaning towards E., was only revealed by excavation.

Stones outside S. Causeway.—Fairly large, long and narrow stone, height at E. 1·3 foot from surface, sloping off at centre westwards, and rising again near W. end to about 9″ from turf. Stump close to two rounded stones a little above turf level, on side of S. rampart.

Two Stones in Ditch.—Two stones in ditch on S.W. One long and narrow, about 8″ in height from turf; the other, an uneven boulder, rising 1 foot above surface.

There are other small stones here and there at Arbor Low, which seem to be hardly worth mentioning, although they might prove to be somewhat larger if exposed by excavation.

The Stone Implements excavated at Arbor Low, 1901.
By Henry Balfour.

Detailed references to the positions in which the various stone implements were found during the excavations are given in Mr. Gray's reports, and the exact position of each is marked upon the plan prepared from his elaborate and very careful survey, which it is hoped may be published later on. The depth at which each implement was found is also noted in the report.

As regards the implements collectively but little need be said, as they are unfortunately few in number, and, while all are of forms well known in the finds of the Neolithic period, with which such forms are usually associated, they are not of a sufficiently typical and distinctive kind to render it absolutely certain that they belong to Neolithic times. That they should be referred to that period seems to me extremely probable, particularly when the facts regarding the nature of the implements are considered in relation to other evidence, viz., the total absence of any objects of bronze amongst the finds, and the fact of what is stated to have been an *early* Bronze Age tumulus having been constructed out of the material which formed part of the original structure of the monument, which must therefore have antedated the tumulus, and, presumably, by a period long enough for the original function and probable sanctity of the circle to have been forgotten. At the same time it must be admitted, in regard to the stone implements hitherto unearthed, that any or all of them *might* have been made and used during the Bronze Age. Simple flakes, flakes with secondary chipping, and 'scrapers' of flint belong practically to all periods. Their manufacture persisted during the metal ages so long as their efficiency as tools and the rapidity with which they could be made rendered them desirable.

Perhaps the most striking implement of those found, and the one which might claim with most justification to be assigned definitely to the Neolithic period, is that numbered 20 in Mr. Gray's report, found near the centre of the circle at a depth of 27 cm. This is a small blade of flint of very broad, leaf-shaped outline, flaked on both sides and rather clumsily shaped, being thicker towards one edge than the other. It resembles a leaf-shaped arrow-head, but may have been hafted and used perhaps as a knife, as the point is extremely obtuse and not very carefully shaped for penetration.

With one or two exceptions, the remaining implements showing any considerable working along the edges may be classed as varieties of the 'scraper' or 'side-tool,' and in this category I should class that numbered 3 by Mr. Gray, who suggests that it may have been a spear-head. It could at most be regarded only as a spear-head in process of manufacture, rejected before completion. It is worked on one face only, and, rough though it is, would serve very well as a scraping tool; the point at one end, if intentional, could have served for cutting grooves. Three well-defined 'scrapers' (Nos. 7, 14, 15) were found in the ditch varying from a very broad, semicircular-edged form to a very narrow 'duck-bill' shape: they are familiar forms. An 'outside flake' (No. 10) shows secondary chipping along two edges, and was probably a scraper: it is evidently but a fragment of a fair-sized flake, broken, perhaps, in use. No. 5 is also a fragment showing some flaking at the bulb end of a small-size flake,

One broken flake (No. 13) shows a very delicate serration along one edge, forming a finely toothed saw. The serration evidently extended along the portion of the flake broken away. This saw must have been intended for delicate work only.

In addition to the implements already referred to, there are several flint flakes showing well marked bulbs of percussion, a few with secondary chipping at the edge; also some which are doubtfully worked; and a certain number of flints were picked up and kept, which prove on inspection to exhibit natural fractures only, and these I have rejected. Mr. Gray very rightly submitted these rather than run any risk of overlooking examples which might possibly betray human agency, however slight.

The finding of six large flakes (No. 17) together is interesting. It is evident that these could not have come by accident into the position in which they were found, and it is virtually certain that they were placed by hand upon the small ledge in the side of the northern causeway. The flakes are of considerable size and weight, and of fine quality black flint which has been weathered white to a considerable depth. It is difficult to determine the use for which they were intended. They are irregular in outline and surface, though their edges are still sharp and undamaged. It is possible that such heavy flakes may have been intended to be used as digging tools, for which purpose they would be not badly adapted; but no *used* examples are as yet forthcoming from the site, and the suggestion is merely conjectural. They may have been purposely covered over at the time for concealment, and forgotten, or they may have been accidentally covered by loose earth falling from the causeway on to the ledge. In either case they have remained as originally placed.

It is greatly to be hoped, if further excavations are undertaken, that the yield of implements may be greater, and that the examples may present more definite features, so that the negative evidence afforded by the absence of metal, if it continues to hold good, may be backed by positive evidence of Neolithic date from the nature of the implements discovered. For the negative evidence to be completely convincing, more extensive exploration is necessary, and the very suggestive nature of the positive results so far obtained by Mr. Gray renders it highly probable that further examination may yield results of great importance.

One point to which I may perhaps be allowed to refer here arises out of the excavation of the ditch to its full depth. The bed-rock bottom presents a very rough and uneven surface, and there does not appear to have been any definite attempts to create a level surface along the ditch bottom by filling in the hollows and levelling in other ways. It is of importance to note this, as it precludes the idea that the fosse itself may have been used for processional or other like purposes. The steepness of the causeway sides forming the ends of the fosse also points towards the same conclusion as regards this matter.

Report on the Human Skeleton found in the Stone Circle of Arbor Low in 1901. *By* J. G. GARSON, *M.D.*

The skeleton found by Mr. Gray near the centre of the Stone Circle of Arbor Low in August 1901 is that of an adult male. The bones are not in a good condition as regards preservation; hence it has not been possible to ascertain from them the probable stature of the individual more nearly than has already been done by Mr. Gray in his report. The upper

part of the brain-case, or calvaria, and part of the face, though much broken and very imperfect, especially the latter, have been pieced together by Mr. Gray in a most creditable manner, so that it is possible to ascertain and determine the most important points in the morphology of the former fairly well. The muscular ridges are well developed, the glabella and brow ridges are well marked and continuous with each other, the most prominent part of the latter being over the inner third of each orbit. The tubera of the parietal bones are prominent, the curved lines on the occipital bone and the surface between them for the insertion of the muscles of the head and neck are well marked; but the mastoid processes of the temporal bones are of very moderate size, or may even be regarded as small. As viewed from the front, the malar bone, which is retained on the left side, shows that the axis of the orbit slants markedly downwards as well as outwards; the orbital processes are of moderate size, and the interorbital width appears to have been of medium size. As viewed from behind, the lateral walls are seen to be nearly vertical but slightly converging, as they rise upwards, and finally curve over to form the vault with a flat or low arch. When viewed from above the outline of the calvaria is unsymmetrical in the occipital and posterior parietal regions, and converges slightly from the tubera of the parietals towards the orbital processes of the frontal with straight sides. On viewing the cranium laterally the profile outline of the mid-parietal region is elevated and bulged upwards: this fulness extends from one tuber to the other, while the frontal region above the glabella follows a graceful curve backwards and upwards to the bregma, and the occipital region is slightly bulged backwards and rounded.

To reduce these general characters to actual figures as far as possible the following are the chief dimensions which the state of the cranium permitted me to determine:—Maximum length, 189 mm.; maximum breadth, 148 mm. These figures give a cephalic index of 78·2, which places it, as regards general form, above the middle of the mesaticephalic group (75–79·9) and shows that the individual when alive had a head slightly rounder than that of the average male of the present population of Great Britain, more brachycephalic than in some parts of the country, but more dolichocephalic than in others. The ophryo-occipital length is 185 mm., the point of greatest length on the occiput being the same as for the maximum length; the projection of the glabella is, therefore, 4 mm. The minimum frontal breadth is 106 mm., and the maximum frontal breadth is 125 mm.; the relative properties of these two measurements to the maximum breadth (the latter being taken as 100) is 71·6 and 84·5 respectively. The biauricular diameter is 130 mm., while the auriculo-bregmatic arc is 316 mm. The horizontal circumference is 530 mm.; the longitudinal arc, from the nasion, over the bregma, lambda, and the occiput to the opisthion, is 377 mm.; the base of the cranium being absent it is impossible to obtain the length of the foramen magnum and basio-nasial length to complete the longitudinal circumference. The length of the frontal portion of this longitudinal arc is 130 mm., that of the parietal 130 mm., and of the occipital 117 mm.; while the chords of these arcs are: frontal, 113 mm.; parietal, 117 mm.; occipital, 97 mm. The relation which the arc bears to the chord may be expressed as an index to indicate the curve of the bone; the chord being taken as 100, the frontal index is 115·0, the parietal index 111·1, and the occipital index 120·6. These indices show that while the curvature of the frontal

and occipital are about normal, that of the parietal is greater than usual. Little can be said about the characters of the facial portion of the cranium, as it is so imperfect. The palate is parabolic in form. The teeth are moderately worn down, especially the molars, and there is a slight deposit of tartar upon most of them.

The osteological characters show that the individual was not of the type found in interments of the Neolithic period, neither do they point to his being of the Bronze Age type, though he was more nearly allied to it than to the former. On the other hand, there are no characters about the specimen which would preclude its being much more recent—even that of a person interred only about a hundred years ago. The extended position in which the body had been laid decidedly supports the view of the interment being of more recent date than the Bronze period, to which I consider the weight of the evidence afforded by the osteological characters also points.

The Committee have special satisfaction in submitting the very careful and exact survey of the circle which Mr. Gray has prepared, and the sectional diagrams of the excavations made under his direction. The former is undoubtedly the most complete survey of the circle ever made, and will constitute a lasting work of reference for future investigations; indeed, it has been prepared with so much care that there will be no difficulty in constructing from it accurate models of the circle and its surroundings. The Committee recommend that the specimens found be eventually placed in the national collection in the British Museum.

Mr. Gray has informed the Committee that about two to three weeks' further excavations of the circle on the lines hitherto pursued will be sufficient to complete the examination of the ditch and rampart. The excavations made during the present year have been confined to the west side of the circle; the eastern half of the ditch and rampart have not been touched, nor have any of the external approaches which it is also desirable to excavate been explored. From personal observations (the circle having been visited during the explorations by the Chairman, the Secretary, and Mr. Lewis) the Committee can confirm Mr. Gray's statements to them, and are convinced of the desirability of the work being resumed at the earliest possible opportunity.

The whole of the money granted by the Association has been expended, and the amount slightly exceeded in the work which has been done.

The Committee apply to be reappointed, and ask that a grant of 40*l.* be placed at their disposal to carry on the investigations which have proved to be so successful and hopeful in their results towards solving the somewhat disputed age of stone circles as regards Arbor Low.

Explorations in Crete.—Report of the Committee, consisting of Sir JOHN EVANS, *K.C.B.*, *F.R.S.* (*Chairman*), Mr. J. L. MYRES (*Secretary*), Mr. A. J. EVANS, Mr. D. G. HOGARTH, Professor A. MACALISTER, *and* Professor W. RIDGEWAY.

IN order to present the results of the season of 1901 in their proper bearings the Committee introduces its Report with a retrospect of British exploration in Crete.

The Cretan Exploration Fund was formed in 1899 with the object of assisting British explorers and the British School at Athens to investigate the early remains of the island, which from indications already apparent seemed likely to supply the solution of many interesting questions regarding the beginnings of civilisation in Greece. To the furtherance of this work, begun in the spring of 1900, the grant of 145*l*. was made last autumn by the British Association.

Already in 1894 Mr. Arthur Evans had secured a part-ownership (completed last year) in the site of Kephala at Knossos, which evidently contained the remains of a prehistoric building. Excavations, to which the fund has largely contributed, begun by him in 1900 on this site and continued during the present year, have brought to light an ancient palace of vast extent, which there is every reason to identify with the traditional House of Minos, and at the same time with the legendary 'Labyrinth.'

The result of the excavations of 1900 was to unearth a considerable part of the western side of this great building, including two large courts, the porticoes and entrance corridors, a vast system of magazines, some of them replete with huge store jars, and a richly adorned room, where between lower benches rose a curiously carved gypsum throne, on which King Minos himself may have sat in council. The second season's work has uncovered a further series of magazines, the whole northern end of the palace including a bath-chamber and an extensive eastern quarter. It was only towards the close of this year's excavations that what appear to have been the principal state rooms first came into view. A triple flight of stone stairs, one flight beneath another, here leads down from an upper corridor to a suite of halls, showing remains of colonnades and galleries. It was at this interesting point that, owing to the advanced season, Mr. Evans was obliged to bring this year's excavations to a close.

Apart from the architectural results already gained, the finds within the walls of the palace have been of such a nature as to throw an entirely new light on the art and culture of prehistoric Greece. Partly still clinging to the walls, partly on the floors of the chambers, were found the remains of a whole series of fresco paintings. Among these the full-length figure of the cup-bearer supply the first real portrayal of a man of the Mycenæan age, while the miniature groups representing court ladies show a liveliness and expression far beyond any work of the kind in contemporary Egypt. Allied to this branch of art are the painted reliefs in *gesso duro*, showing a force and naturalism for which no parallel can be found till the great days of Greek sculpture some ten centuries later. To the remarkable bull's head discovered last year the more recent excavations have added parts of human figures, in which the muscles and even the veins are reproduced with a singular mastery of execution.

The marble mouth of a fountain in the shape of a lioness's headand a triton shell of alabaster, together with many other beautiful stone vessels and architectural ornaments, also evidence the high level already attained in the sculptor's art. Among the minor arts represented is that of miniature painting on the back of crystal and intarsia work of ivory, rock-crystal, enamel, and precious metals, of which a splendid example has been found this season in the remains of a royal draught-board. Other finds illustrate the connections with ancient Egypt and the East. Part of a small diorite statue from last year's excavations bears a hieroglyphic inscription fixing its date about the beginning of the second millennium

B.C., while a more recently discovered alabaster lid bears the cartouche of the Hyksos King, Khyan. A fine cylinder of lapis lazuli, mounted with gold and engraved with mythological subjects, bears witness to the early connections with Babylonia.

But of all the discoveries made within the palace of Knossos the most interesting is the accumulated evidence here for the first time afforded that there existed on the soil of prehistoric Hellas a highly developed system of writing some eight centuries earlier than the first written Greek monuments, and going back six or seven centuries, even before the first dated record of the Phœnician script. A whole series of deposits of clay tablets has come to light, many of the most important of them during last season's excavations, engraved with a linear script, often accompanied by a decimal system of numeration.

That these documents largely relate to the royal stores and arsenals is seen by the pictorial illustrations with which the inscriptions are often accompanied. Others, in which signs representing men and women frequently recur, probably contain lists of slaves or officials. Others again of a different class may, perhaps, ultimately reveal to us fragments of contemporary records or the actual formulas of Minoan laws.

Besides these linear tablets there was discovered a separate deposit of clay bars and labels containing inscriptions of a more hieroglyphic class. Although contemporary with the linear tablets, the script on these is apparently of quite distinct evolution, and in all probability in a different language. The characters answer in fact to the sign-groups already observed in certain seal-stones mostly found in the east of Crete. The hieroglyphs themselves present many parallels to the presumed pictorial prototypes of Phœnician letters.

Beneath the palace itself and the adjoining houses, and underlying the whole top of the hill, was also a very extensive Neolithic settlement. A detailed account of the exploration of this Neolithic settlement, the first of the kind uncovered in Greece, will be communicated by Mr. Evans to Section H. The relics found, such as the small human figures of clay and marble, supply the antecedent stages, hitherto wanting, to the Early Metal Age Culture of the Ægean Islands.

In addition to the assistance given to Mr. Evans in his work at Knossos, the Cretan Exploration Fund has contributed towards various works of exploration in the island undertaken under the auspices of the British School at Athens. In 1899 the late Director of the School, Mr. D. G. Hogarth, excavated a series of prehistoric houses in the lower town of Knossos. He found in these many remarkable painted vases, showing that a highly developed ceramic art flourished here already before the days of the civilisation known as Mycenæan. A large number of similar houses await exploration; in fact, the whole plan of the early town could probably be recovered. Mr. Hogarth further successfully explored the great cave of Zeus on Mount Dicta, discovering remains of a prehistoric sanctuary and large deposits of votive bronze figures and other objects, among which the double axe, the symbol of the Cretan and Carian Zeus, was specially conspicuous.

During the present year Mr. R. C. Bosanquet, the new Director of the British School, has carried out an exploration of the site of Praesos, in the easternmost region of Crete, in historic times the chief civic centre of the original Eteocretan element of the island. The remains on the actual site of Praesos proved to belong to the geometrical and later periods. A

remarkable inscription was found, however, the second of its class, written in Greek characters of the fifth century B.C., but composed in the old Eteocretan language. Two sanctuaries with votive deposits also came to light, and the remains of a large public building of Hellenistic date, which may have been an 'Andreion' of the kind in which the Cretan citizens met for common meals.

This season Mr. Hogarth has also been enabled by a grant from the fund to explore an ancient site at Zakro in the extreme east of the island. He has there uncovered a small Mycenæan town with well preserved remains of the lower part of the houses and magazines, and a pit containing fine examples of early pottery. But the most important discovery was a deposit of clay impressions of Mycenæan gems and signets containing 150 types, some of them throwing a new light on the early cult of Crete. Among other subjects represented was the Minotaur, which also occurs on a seal impression recently discovered in the palace at Knossos. Furthermore, some interesting cist-graves were found in caves about Zakro. These yielded incised and painted pottery of the pre-Mycenæan age, including types novel in Crete but familiar in Cyprus and Egypt. The general result has important bearing on the origin and history of Mycenæan civilisation in Crete.

Other interesting sites, already previously secured for British excavation, remain to be explored. The Executive Committee of the Cretan Exploration Fund, however, are of opinion that, before devoting any sums towards breaking new ground, a sufficient amount shall be raised to enable Mr. Evans to complete his excavation of the palace of Knossos, a considerable part of the cost of which has already fallen on the explorer's shoulders. The large scale of the work, on which throughout the whole of last season 200 workmen were constantly employed, makes it necessarily costly, and in this case, in addition to many other incidental items of expenditure, a great deal has to be done towards the conservation, and in some cases even the roofing-in, of the chambers discovered. It is estimated that a sum of between one and two thousand pounds will be necessary for the adequate completion of this important work. The unique character of the results already obtained is, however, so widely recognised that the Committee confidently trust that no financial obstacles will stand in the way of this consummation.

Report on Excavations at Praesos, in Eastern Crete.

Praesos, the ancient capital of the aboriginal Eteocretans, lies high on the central plateau of Eastern Crete. The excavations at Praesos, conducted in the spring of 1901 by Mr. R. C. Bosanquet, the Director of the British School at Athens, with the aid of Mr. J. H. Marshall and Mr. R. D. Wells, architect, did not bear out the expectation that the Eteocretan capital would prove to have been a centre of Mycenean culture. It is true that the Acropolis yielded a product of pure Mycenean art under singular circumstances. A large lentoid gem, with a representation of a hunter and a bull, was found embedded in the mud-mortar of a late Greek house: it must have been plastered in unseen along with the earth from an adjacent rock-cut tomb, which had evidently been emptied by the Hellenistic builders.

But no other vestige of Mycenean occupation was found upon the site of the later city. The waterless ridge, encircled by deep ravines, offered

nothing to primitive settlers. The earliest remains lie a mile away in a lateral valley near a spring. Here are several groups of megalithic walls, the chief of which was shown by excavation to be a sub-Mycenean homestead. Its strictly rectangular plan, its massive thresholds, the spiral ornamentation of large jars in its cellars, show that, whatever fate had overtaken the cities on the coast, a certain standard of good workmanship had been their legacy to the people of the hills. Nearer the city two tombs of the same period were discovered: the one, a square chamber with a dromos, yielded parts of two painted *larnakes*, thoroughly Mycenean in design, a gold ring, a crystal sphere, parts of a silver vase, and a quantity of iron swords. The other was a well built bee-hive tomb, differing from the usual type in being entered through a vestibule: it contained an enormous mass of geometric pottery, an openwork gold ring, a bronze fibula, and other objects in gold, ivory, and Egyptian porcelain. In the same neighbourhood a number of later tombs were opened, ranging from the geometric period to the fourth century. Among the numerous geometric vases there are several new types, in particular a vessel in the form of a bird, and a slender jug painted with delicate white patterns on a black ground. The later graves yielded jewellery in gold, silver, and crystal.

Prominent among the considerations which caused Praesos to be put upon the programme of the Cretan Fund was the fact that an inscription in an unknown tongue, presumably the Eteocretan, had come to light there, and the hope that others might be found. It was dug up at the foot of the Altar Hill, a limestone crag precipitous on three sides which dominates the south end of the site, and had probably fallen from the level summit, long known to the peasants as a hunting-ground for 'antikas.' More fortunate than Professor Halbherr, who made a small excavation here with the same object before the Cretan revolution, we obtained a second and longer inscription of seventeen lines, and apparently in the same non-Hellenic language, close to the entrance steps of a *temenos* on the hill top. It must have been a frequented place of sacrifice, for the rock was covered several feet deep with a deposit of ashes, burnt bones, and votive offerings of bronze and terra-cotta. The terracottas, ranging from the sixth to the fourth century, are important as giving a glimpse of a local school of artists working in clay (for Crete has no marble of her own, and Praesos, at any rate, imported none) and possessed of an independent and vigorous style. The great prize is the upper part of an archaic statue of a young god, half the size of life: the head and shoulders are intact; the remainder has disappeared. An equally well preserved head, with fragmentary body, of a couchant lion is a further revelation of early Cretan sculpture. The bulky fragments of another lion, life-sized, later and feebler in style, prove the persistence of the local method. Among the bronzes there is a noteworthy series of votive models of armour, helmet, cuirasses, and shields. The pottery shows that the Altar-hill was frequented from the eighth century onwards.

By this time Praesos had probably become the religious and political centre of the district, a primacy for which it is admirably fitted by its position at a meeting place of valleys midway between the two seas. The Acropolis was fortified, the water of the distant spring brought to its foot in earthenware pipes, and a small temple built on its summit. The upper slopes of the Acropolis, though much denuded, yielded two archaic bronzes. Trial-pits in the deeper terraces below revealed only Hellenic

things, plainly built houses of limestone, roadways and cisterns, and a rubbish pit full of terra-cottas. A building larger and more massive than the rest was completely excavated: it contains eight rooms and has a front seventy-five feet long. Outside the town two minor sanctuaries were investigated: one adjoining the spring already mentioned contained large terra-cotta figures of a goddess of quite new type. A survey of the whole site was made by Mr. Wells, and a systematic exploration of the surrounding country by Mr. Marshall.

Although Praesos was barren of Mycenean remains, they are evident enough at Petras, on the modern harbour of Sitia, seven miles to the north. I made some trials here in June. Nine-tenths of the site has been ruthlessly terraced by its Moslem owner, and would not repay a large excavation. The remaining tenth is occupied by cottages, and here under the roadway it was possible to uncover one side of a large building containing pithoi and kamereis vases. On the hill-top there remain a few foundations of a large mansion, and outside the walls—for Petras is unique among early Cretan sites in possessing remains of fortifications—was found a rubbish heap of the now familiar type, yielding whole cups and lamps and shreds of earthenware and steatite. Ten miles east of Petras, across the Itanos peninsula, is another early site, Palaiokastro, which has been sadly mauled of late years by clandestine excavation. In the course of one of his exploring journeys Mr. Marshall made a remarkable discovery here. Heavy rains—the same that flooded Mr. Hogarth out of his quarters on the beach at Zakro—had exposed the corner of a very fine larnax. The native diggers had not noticed it, and he lost no time in securing it, and some fine vases for the Candia museum. One of its four picture-panels represents a double axe planted upright upon a column, an important illustration of the axe and pillar cults discussed by Mr. Evans in the 'Journal of Hellenic Studies.'

The Micro-chemistry of Cells.—Report of the Committee, consisting of Professor E. A. SCHÄFER (*Chairman*), Professor E. RAY LANKESTER, Professor W. D. HALLIBURTON, Mr. G. C. BOURNE, Professor J. J. MACKENZIE, and Professor A. B. MACALLUM (*Secretary*). (*Drawn up by the Secretary.*)

THE research of the previous year on the distribution of phosphorus in animal and vegetable cells was continued with the view of making the field of investigation as large as possible. The results of these observations cover a large number of details, but these, while corroborating the conclusions advanced in the last report on the subject, have not furnished any additional generalisation which merits special mention here. The paper embodying all the results will, it is hoped, be ready for publication in a few weeks.

Micro-chemical Localisation of Oxidases.—The work of the previous year on oxidases was continued, and efforts were made to localise them micro-chemically. After a considerable amount of experimenting with different leuco-compounds it was found that the reagent mixture recommended by Rohmann and Spitzer[1] for the detection of oxidising enzymes

[1] 'Ueber Oxydations-Wirkungen thierischer Gewebe,' *Ber. d. d. Chem. Gesell.*, 1895, vol. xxviii. p. 567

in extracts of animal tissues was of considerable service if used in dilute solutions on the protophytan cell. It consists of a mixture of α-naphtol, paraphenylendiamin, and soda in the proportions by weight of 12, 9, and 10, and when freshly made should have only a slight yellow-red tint; but on exposure to the air for some hours it gradually becomes violet and then blue, due to the formation of indo-phenol. The reactions which occur thus and in the cell may be indicated as follows:—

$$(a)\quad C_6H_4(NH_2)_2 + C_{10}H_7OH + O = NH\left<\begin{array}{l} C_6H_4NH_2 \\ C_{10}H_6OH \end{array}\right. + H_2O$$

$$(b)\quad NH\left<\begin{array}{l} C_6H_4NH_2 \\ C_{10}H_6OH \end{array}\right. + O = N\left<\begin{array}{l} C_6H_4NH_2 \\ C_{10}H_6O \end{array}\right. + H_2O$$

When the reagent is poured on the fresh protophytan threads and allowed to act on them for 20–30 minutes, or even for 2–3 hours, the fluids in the cell spaces (*Spirogyra, Ordogonium,* &c.) are often coloured violet blue, and contain small sheaves of the blue crystals of indo-phenol. This indicates the occurrence of oxidising enzymes in the fluids of the cell spaces or cavities, but no coloration was found in the protoplasm itself or in the nucleus, and the chromatophor itself gave only a very faint reaction in a few cases, except in the immediate neighbourhood of the pyrenoids, when frequently a deeper reaction was observed. That the blue reaction was not due to the diffusion of the colouring material from other points is indicated by the fact that indo-phenol, to which the blue colour is due, is almost insoluble. It is to be noted that in the report of last year the conclusion that the chromatophor contains no oxidising enzymes was based on the fact that that organ did not appear to be affected when extracts of the enzymes were made by hydraulic pressure from the cells. This conclusion, in view of the fact given above, must now be considered untenable. The reagent was also employed on the Cyanophyceæ to determine the presence of oxidases in these non-nucleated forms, and it was found that one is present in the peripheral coloured zone and its granules in these cells, but the 'central body,' which is considered by some to be the homologue of the nucleus of the higher forms, is absolutely unaffected, as are also its granules, by the reagent. The peripheral zone would appear to correspond to the cell fluids and chromatophor of higher Protophyta, while the 'central body,' so far as absence of an oxidase is concerned, corresponds to the nucleus and cell protoplasm of *Spirogyra.*

The reagent cannot be used to detect the peroxidases, so that the micro-chemical localisation of these enzymes could not be determined. The difficulties in the employment of solutions of guaiacum for this purpose on fresh cells, or even on alcoholic preparations of them, were found to be insuperable.

The main point to be noted in all these observations is that the oxidases are not components of the living framework of the cells, but are dissolved in the fluids which bathe that framework and circulate in the cell spaces and cavities. In consideration of the relations which these fluids bear to the surrounding media it would seem proper to regard these oxidases, not as enzymes, but as oxygen-carriers, playing the part in the cell mechanism that hæmoglobin does in the animal body.

On the Nature of Hæmosiderin.—Dr. E. N. Coutts, under Professor Mackenzie's direction, investigated the composition of hæmosiderin from a micro-chemical point of view and ascertained a number of interesting facts. He found that hæmosiderin of liver cells is different from that of the alveolar cells of indurated lung in regard to the way in which the iron is held, as well as in the chemical reactions of the basic material of the granules themselves. The iron of the hepatic hæmosiderin is in an inorganic form easily extractable with very dilute acids, and to a certain extent also by prolonged action of distilled water. The iron in hepatic hæmosiderin is also readily demonstrated by acid ferro-cyanide solutions, or by ammonium sulphide almost immediately after their application, this indicating that the iron is not firmly bound in the substance of the granules. That it is inorganic is shown also by its reactions with pure dilute hæmatoxylin solutions. In the pulmonary hæmosiderin granules the iron seems to be combined differently, yet in an inorganic form, probably with a proteid body, for on digestion with artificial gastric juice the granules diminish in size and lose their iron. In both pulmonary and hepatic hæmosiderin granules the iron may be extracted, with the result that the colour, shape, and size of the granules may be unchanged, but the residual matrix in pulmonary hæmosiderin is much more readily affected by stronger acids than is the case with hepatic hæmosiderin. The residue in neither seems to show any chemical affinities with hæmatoidin (bilirubin) or with hæmatoporphyrin.

The conclusion from these observations is that hæmosiderin is not a chemical compound, that it is not uniform in composition, and that it is for the most part a mixture of an inorganic iron compound with a brown-yellow iron-free substance.

The Committee ask to be reappointed.

The Chemistry of Bone Marrow.—Interim Report of the Committee, consisting of Professor E. A. Schäfer (*Chairman*), Dr. R. Hutchison (*Secretary*), Dr. Leonard Hill, *and* Professor F. Gotch.

The work of the Committee has been considerably retarded by the difficulty of obtaining a sufficiency of material for examination and analysis. A certain amount of progress has, however, been made in the estimation of the nucleins and nuclein bases in red marrow, and the investigation of the proteids has been begun. So far (1) a histon and (2) a nucleo-proteid have been isolated, and the further investigation of these bodies is now being proceeded with. Hereafter it is hoped that the estimation of the iron compounds in marrow will be undertaken.

The Morphology, Ecology, and Taxonomy of the Podostemaceæ.—Report of the Committee, consisting of Professor Marshall Ward (*Chairman*), Professor J. B. Farmer (*Secretary*), *and* Professor F. O. Bower.

The Committee report that the grant of 20*l.* made at the Bradford meeting of the British Association has been expended by Mr. J. C. Willis in the prosecution of the research above named.

Several districts of the Indian Peninsula have been travelled over, and Mr. Willis' investigations have thrown much light on the habits, development, and affinities of the plants composing the Order.

The first instalment of his memoir, dealing especially with the classification of the Indian forms, is nearly ready, and will shortly be followed by a second paper on the morphology and natural history of the species.

As the object of the grant has now been fulfilled, the Committee do not ask for reappointment.

Fertilisation in the Phæophyceæ.—Report of the Committee, consisting of Professor J. B. FARMER (*Chairman*), Professor R. W. PHILLIPS (*Secretary*), Professor F. O. BOWER, *and* Professor HARVEY GIBSON.

THE Committee report that the grant of 15*l*. made at the Bradford meeting has been expended by Mr. J. Ll. Williams in connection with the above research.

Mr. Williams' results are now practically complete, and will shortly be embodied in the form of a memoir.

The Influence of the Universities on School Education. *By the* Rt. Rev. JOHN PERCIVAL, *D.D., Lord Bishop of Hereford.*

THE subject before us this morning, as I am given to understand, is not the general influence of universities on national life and character,—a subject of the highest interest and importance, and nowhere better illustrated than in Scotland,—but simply the consideration of some practical questions suggested by the relationship in which our ancient English universities stand to the education given in our secondary schools.

And, although we are met on Scottish soil, and may very well hope to obtain some help and guidance from Scottish example, as I have no direct personal experience of the Scotch University system, though I possess a highly prized degree conferred by your most ancient university, I must be content to base my observations and suggestions exclusively on my English experience.

I even leave out of my purview the newer English foundations, such as the University of London, the Victoria University, the various university colleges of our great provincial cities, and that latest birth of time, the University of Birmingham.

It is from no lack of appreciation that I do this, but partly because, as yet, these modern institutions do not exercise the same influence as the older universities on our general system of secondary education, and partly because, having so lately grown up under the pressure of actual local or national needs, they are not open to the same criticisms.

Our great English universities have till quite recently, as regards their direct action and influence, been to a large extent, we might almost say in the main, the universities of the privileged and the professional classes. Within my own memory they were indeed virtually monopolised by those members of the Established Church who belonged to these classes or were

seeking to enter them. To the mass of the people they were something vague and far off.

Sixty years ago a distinguished German, in his description of them, said that their aim was to produce gentlemen, especially Tory gentlemen; and I am not sure that any of us could prove him to have been altogether mistaken.

But for half a century the process of nationalisation has been going steadily if not rapidly forward. It has been and is the earnest desire of the men who inspire and direct our university life to make them national institutions in the best and truest and broadest sense of the term; and they are, I feel sure, ready to give sympathetic and favourable consideration to any criticism or suggestion which is likely to help towards this end.

Thus I venture to think they will welcome the discussion by so weighty a body as the British Association of these very practical questions:—How do our ancient universities act with special or directing or determining influence on English school education? And in connection with this influence are there any reforms which would be clearly beneficial?

The answer to such inquiries has to be mainly sought through observation of the examinations they conduct or require, the use they make of their endowments, and the type of teachers they train and send forth.

Through its examinations the university largely determines the curriculum or relative amount of attention bestowed on different subjects of study in the schools that prepare for it.

Through its endowments and prizes it fixes the bent of study to be pursued by the most promising and ambitious students; and finally, by the stamp it puts on the teachers sent out, their attainments, their tastes, their aims, opinions, and ideals, it sets the tone and tendency of both life and work in the wide field of school education.

I. As regards examinations we have to look chiefly at—

(1) Examination of schools or of boys and girls still at school.
(2) Entrance examinations to colleges or to the university.
(3) Examination of students during the university course.

By their school examinations, such as the local examinations, the examinations of the Oxford and Cambridge Joint Board, and examinations for commercial and other certificates, experience shows that the universities have done a very good and useful work, and they have done it in a liberal and progressive spirit.

The committees charged with this work have been allowed a tolerably free hand; they have sought the best practical advice, and they have aimed at consulting the needs of different types of school, whilst careful to maintain a reasonable standard of proficiency as a qualification for their various certificates.

If there are defects in any of these examinations the authorities of schools and public opinion are to a great extent responsible for their continuance.

But when we turn from these outside examinations to the conditions of entrance to the university itself it must be admitted that we meet with some survivals that seem altogether out of date, and some obvious deficiencies that call for attention and reform.

Taking the case of Oxford, with which I am more familiar, it is to be noted that the examination known as Responsions or its equivalent is

practically the wicket gate through which every student must enter the University. The various colleges are free to admit students on their own terms with or without examination, but as a matter of practice it is usual for a college to require the passing of Responsions either before commencement of residence or in the course of the first term, so that for actual influence on the ordinary curriculum of secondary schools we may disregard all qualifying entrance examinations except this one.

What, then, does the University in this examination require of a boy fresh from school?

Turning to the examination statutes we find that every candidate desiring to pass Responsions or its equivalent examination has to reach the requisite standard of attainment in the following stated subjects, and in these only :—Latin, Greek, Elementary Mathematics.

So much for the subjects required. But a glance at the papers set will show that as regards the literary portion of the examination the study encouraged is almost exclusively grammatical and of a very rudimentary type.

The writing of elementary Latin prose, the translation of passages from one or two prepared books in each language, and the answering of questions on elementary grammar form the staple of the examination.

No knowledge is required of the art, or literature, or history, or general life of Athens or Rome, and little or no inquiry seems to be made even as to the authors or contents of the books specially prepared.

The mathematical part of the examination is also open to criticism, though perhaps in a less degree.

But the really surprising thing is that natural science still meets with no recognition, modern languages are ignored, and no questions are asked even as to the candidate's knowledge or ignorance of our own language and literature. Here, then, it must be admitted, is some room for expansion. We are even tempted to pause and inquire whether we have not stepped back into some earlier century; and I venture to think that it would be difficult to point to any single educational reform which is more urgently needed or would be likely to produce a more wholesome effect on the teaching in our secondary schools than a reform of this examination.

In the first place if it were made permissible to offer certain equivalents in place of Greek, this single modification would bring our universities into touch with that large and increasing group of modern schools or modern departments in schools which are now suffering from lack of this connection.

The existing requirement of Greek from every candidate, together with the accompanying exclusion of modern languages and natural science from this examination, practically dissociates this whole class of modern schools or departments in schools from direct university influence, and the effect is found to be specially unfortunate in the modern departments of the larger secondary schools.

Whatever may be a boy's ultimate aim or profession or business in life, if his intention is to pass through the university these conditions amount to a warning that he had better avoid a modern school or modern department.

Consequently such schools or departments are very liable to become the refuge of the dull or the idle or those who are preparing for nothing in particular, so that standards of effort and attainment are inevitably

lowered. In drawing attention to the consequences of these antiquated university arrangements I desire to say that I am not raising theoretical or hypothetical objections to them, but simply speaking of what I have seen and known in one school and another; indeed, I would claim that throughout this paper I have been careful to bear in mind the old Newtonian example which is, I imagine, sometimes disregarded even at the British Association, 'Hypotheses non fingo.'

Thus, as the result of my personal experience, the first reform I would advocate is that Responsions without Greek should be made an avenue to a university degree for all candidates who can reach a good standard of attainment in certain equivalent subjects of study.

So much for our first change in the direction of liberty of choice.

We may now go on to consider whether or how far any other changes would effect some improvement in the kind and quality of ordinary school education.

So far as the school curriculum is influenced by this examination, with its rigid exclusion of everything but elementary mathematics and the grammatical study of two dead languages, it must be obvious that it would be improved by an infusion of subjects and methods, the greatest of all needs in our English education being scientific methods, that would help to develop such qualities as observation, taste, thought, and interest in the world around us.

With this view I venture to put the question whether the following scheme of requirements on entering Oxford or Cambridge would not constitute a reasonable substitute for the present Responsions or Little Go:—

1. Latin.—The examination to include the translation into English of easy unprepared passages, and also some questions on a selected period of Roman history and literature.

2. Elementary mathematics.—More attention to be given to scientific arithmetic and to easy original work in geometry.

3. The elements of natural science and scientific method.

4. An elementary knowledge of either French or German or Italian.

5. English.—The examination to include—

(*a*) English composition.

(*b*) Questions on some period of English history and literature.

6. Greek.—The examination to include translation into English of easy unprepared passages and also some questions on a selected period of Greek history and literature; or

6*a*. French, or German, or some branch of natural science.—The standard required to be such as to show that the candidate is fitted to enter on an Honour Course of university study.

It would be reasonable that any student who had passed in three of the six subjects here required should be allowed to commence his residence in the university on condition that he pass in the remaining three before admission to any other examination in the university course. As university study tends to become more specialised it is all the more necessary thus to secure at the outset a good preliminary liberal training.

Such a scheme as is here indicated would do this, and it would exercise a most wholesome influence on school education generally. On the

one hand it would compel all schools preparing students for the universities to give a fair share of attention to modern and scientific studies, and more attention than is generally given to our own language and literature; whilst it would at the same time interpose a check on the mischievous tendency to premature specialisation of study whilst a boy is still at school.

To these suggestions I have to add one more.

This examination, like some others at the university, is a purely 'pass' examination, in which no opportunity is offered to the candidate of winning any honours, and no mark of distinction can be gained by work of unusual merit.

In my judgment the continuance of any such pass education is educationally a grave mistake, and I desire to see it made a rule that the university will give marks of distinction for work of superior merit in every examination which it conducts.

The reasons in favour of such a change are sufficiently obvious, the surprising thing being that the pass examination, with its corresponding type of university student known as the 'passman,' should have been left to survive into the twentieth century.

A standard which every student is required to reach as a preliminary to further instruction or as the qualification for a degree which is understood to be within reach of any person of ordinary intelligence is, of necessity, a comparatively low standard.

It represents the minimum of attainment qualifying for a certificate, or diploma, or degree. Not to win it is to be a failure.

The natural result is that a large proportion of the students who offer themselves for examination, and are, in fact, capable of reaching a considerably high level of attainment, are content to aim at a minimum instead of a maximum standard. This in many cases means the loss of intellectual interest at the very time when it ought to be cherished and stimulated, a loss which degenerates in not a few instances into downright idleness and waste.

The pity of it is that many of those to whom the preparation for a pass examination, in which failure is discreditable and success no honour, is irksome drudgery would become keenly interested in the very study which is now a weariness if their ambition were roused by the hope of some distinction to be won in connection with it.

So, then, I plead for such changes as I have here suggested in the belief that the effect would be to send a fresh stream of intellectual activity through many of our schools, to give a fair field to modern and scientific studies, and to draw out the undeveloped capacities, the dormant faculties and gifts of many of our boys and young men, whilst doing no harm to the traditional classical culture of either school or university.

It may possibly be alleged in some quarters that my proposed requirements would lay too heavy a burden on many candidates for admission.

The argument will no doubt be used that by requiring an acquaintance with so many subjects we should overweight the learner or reduce the knowledge of each subject to a superficial smattering. It is better, we shall be told, to concentrate and make the standard to be reached in any subject studied a fairly high one, and thus give some real mental discipline. To this familiar line of argument a sufficient answer is not far to seek. In the first place the candidates, as a rule, are at least

eighteen years of age, so that they have had a considerable period for preparation; and it is open to question whether the present standard of knowledge attained is in all cases a very high one, or one that guarantees any great amount of valuable intellectual training. Even within the narrow field of the present examination a large proportion of the candidates would, I fear, be sorely puzzled by very simple riders on the first Book of Euclid, or by any straightforward piece of narrative in Thucydides, or Herodotus, or Livy, or Tacitus, which they had not seen before, to say nothing of Horace or Virgil, Sophocles, Homer, or Plato.

The fact is that no experienced person looks upon these university requirements as in any sense representing what candidates of eighteen years of age about to enter on a university course ought to have studied. Neither does any experienced school teacher doubt the capacity of the ordinary boy or girl, if properly trained in habits of industry and attention, to sufficiently master my schedule of subjects. To the plea that, the present limited range of subjects being so indifferently mastered, it would be folly to widen the range, the real answer is that the English schoolboy is, as a rule, a very practical person. He has no great enthusiasm about learning for learning's sake; he has come somehow to understand that a certain minimum will serve his purpose when he presents himself at a college in Oxford, and so his mind is quiescent in front of his Xenophon, or Euripides, or Virgil, or Euclid, or it is occupied with other things.

He is commonly described as an idle boy, but this, I venture to think, is a misnomer.

Give him a practical motive for learning, extend the range of his practical interest in subjects to be studied, stir his practical instincts, rouse his personal ambition by making it clear to him that he may win some distinction in such and such subjects for which he has shown some aptitude or ability, and he sets his mind to work and learns what is required of him with an amount of success which is not seldom a surprise both to himself and to his teacher. So experience shows us to what an extent our antiquated educational arrangements leave capacity undeveloped and let young lives run to waste.

My concluding observation on this subject of examinations is that I should prefer to see the examination of secondary schools retained, as far as possible, within the circle of university influence.

Even in the presence of the right honourable gentleman who presides over us this morning I must pluck up courage to say that I should regret to see it established exclusively at Whitehall. My hope is that whatever reforms are instituted the headquarters of this work may somehow be maintained in connection with our universities, so as to secure that the men who examine may be familiar with the current work of both school and university, and, as a rule, men who either are or have been themselves engaged as teachers.

II. I now turn to the influence exercised through university or college endowments. This part of the subject is of such importance that it might advantageously be considered by a fresh university commission at no very distant date, experience having shown that the reforms of previous commissions stand in need of some further revision.

The system of election by merit or unrestricted open competition, ridding us, as it has so largely done, of a system of patronage and privilege and arbitrary preferences has brought great benefits to English life;

but in regard to educational endowments, both at school and university, it is now seen to have been made in some respects too universal and absolute.

One result of our present system is that prizes go too exclusively to the well-to-do.

A considerable proportion of the endowments both at school and college, given as scholarships or exhibitions, is enjoyed by those who do not need such pecuniary assistance. There is consequently a certain amount of waste which might be avoided.

But a much stronger objection to this unrestricted competition is that the endowments in many cases thus become the rewards, not of the most promising ability, but of the most elaborate and expensive preparation: 'To him that hath shall be given.'

These considerations suggest that, whilst the principle of open election by merit should be scrupulously maintained, the value of open scholarships and exhibitions, both at school and university, should be considerably reduced, and the amount thus saved should form a supplementary exhibition fund out of which the authorities might increase the emoluments of every meritorious scholar so elected who applied and gave proof that his pecuniary circumstances were such as to call for this addition. They suggest, further, that there should be some modified return to the allocation of endowments to districts (the poorer country districts, which are sometimes the birth-places of boys and girls of talent, having specially suffered by the reforms of the last half-century), care being taken so to arrange the allocation as to encourage and cultivate ability and to give that further and general intellectual stimulus which is given by arousing local interest and enlisting in the cause of educational development the spirit of local patriotism, thus stirring a good deal of intellectual ambition which now lies dormant.

The ancient country grammar schools, owing to their connection with some college at Oxford or Cambridge, undoubtedly exercised in their day a stimulative intellectual influence which has been to some extent lost in some rural districts of late years.

Looking, then, to the needs of our rural districts I venture to put it forward as a suggestion which deserves favourable consideration that not less than 5 per cent. of the funds now awarded at Oxford and Cambridge in scholarships and exhibitions might be formed into a 'county scholarship fund,' and offered in due proportions to the various counties on condition, in every case, that the county educational authorities provide an equivalent sum for the same purpose.

These scholarships to be confined, in the first instance, to candidates born and educated in the county, and to be tenable in any college of either university.

Now that the Honour Schools of the university are thrown open to women, a fair proportion of these scholarships should be made available for girls.

I commend this suggestion to the universities as a reasonable and prudent mode of casting their bread upon the waters. The result could hardly fail to be a wide extension of their influence, tending to make them more truly national, whilst it would give a considerable stimulus to intellectual interest, culture, and progress in every district thus aided.

My other criticism on the present use of endowments has reference to the premature specialisation encouraged and fostered by the offering of

scholarships for special subjects. The scholar elected for proficiency in classics and mathematics combined, and prepared to read for double honours, is said to be almost extinct at Oxford, whilst the literary critic complains that in some cases scholarships in mathematics and natural science are awarded to candidates who are almost entirely destitute of the elements of a liberal training.

It may, I fear, also be said that history scholarships are at times awarded to boys who have been diverted to exclusive reading of history at a time when they would have been better employed on the general curriculum of school work.

And it might even be urged that in many schools the classical training is little more than a sort of old-fashioned specialisation on the learning of two languages, with very little of that training of thought, or taste, or faculty which would be given by an adequate amount of attention to a wider range of subjects, and, what deserves to be specially noted, with no training at all in scientific method.

Whatever force there may be in these various allegations, it must be obvious that, in so far as premature specialisation is thus encouraged by the universities, their influence on our schools is being exercised to the detriment rather than the encouragement of a truly liberal and well balanced educational system.

On this theme I desire, in conclusion, to support what I have been saying by calling into the witness-box a very distinguished living authority who can speak to you from a direct personal experience of both school and university education extending over half a century—Dr. Butler, the Master of Trinity College, Cambridge, and formerly Headmaster of Harrow.

In an address published about a year ago he says: 'A new creed seems to have reached us from some unaccredited educational Mecca that man lives by literature or science alone, and that schools live by scholarships.

'There has arisen in our schools a modern Polyphemus, one-eyed, misshapen. Under his new name of specialisation pupils and teachers bow down before him, cultivating exclusively just one part of the mind and one only, and that sometimes the least social and the least human, as if the boy were made for the subject of study and the emoluments attached to it, and not the subject and its emoluments for the boy.

'It is, for instance, one of my privileges,' he tells us, 'in the college of Newton, and Bacon, and Tennyson to have a share in conducting entrance scholarship examinations.

'In connection with one of these examinations I take up the English essay paper or the paper of general questions which by a recent and refined barbarity, sanctioned as yet by only a few colleges, all the candidates at Trinity are now obliged to attempt, and the English work shown up by a considerable proportion of the candidates is simply appalling.' Such is the description given of candidates for the prizes offered by the greatest of Cambridge colleges, and we may fairly ask, If this is the green tree, what of the dry?

'I know,' he adds, 'from happy experience the excellent English which many schoolboys are able to write. But in the essays I have in my thoughts you can detect, after the kindliest search, no mind, no arrangement, no substance. It would seem as though no topic had an interest for the writers, and that they had, so far in their lives, found almost

nothing to think, to feel, to say. And who, as as a rule, are these unfortunates? They are the boys who have been specialised in that modern phrontisterion which prepares them to win scholarships in special subjects.' And these subjects, it must be confessed even here, are generally mathematics and natural science. If time permitted I might extend my quotations from Dr. Butler's criticism, a criticism which cuts in various directions, like a two-edged sword; but I must be content to note his practical conclusion: 'It seems to me tolerably certain,' he says, 'that we must ere long reconsider our methods, and, if the phrase may be permitted, redistribute our bribes.'

My observations on the topics already dealt with have run to such length that I must not tax your patience farther. I therefore limit what I have to suggest on the influence exercised by our universities through the training of teachers to a few brief concluding words.

As a rule the authorities of secondary schools prefer to employ university graduates in all branches of school education, and it is most desirable that this preference should be encouraged and assisted by every possible means; for there is no better service which the universities can do to the nation than that of training and sending out highly qualified teachers.

And yet till quite recently no attention has been given to this aspect of their work apart from the general courses of study which are provided equally for men who are looking forward to other professions or to no profession at all.

It may possibly be argued that it is not the business of the university to give pædagogic any more than medical, or legal, or industrial, or commercial, or any other form of technological training.

This, however, is only partially true, seeing that in the first place a university cannot properly fulfil its function as a teacher of its own students so long as it continues to give no training in the art of teaching, and in the next place the relationship in which the universities stand to school education is entirely different from their relationship to the various professions and occupations of later years.

Thus we may fairly argue that it is high time for our ancient universities to give more special attention to educational methods, and more encouragement than has hitherto been given to the selection of such courses of study and such combinations of subjects as will form the best equipment for that large body of students who year by year go out direct from the universities to the work of teachers in secondary schools.

I plead for these various reforms on the ground that, whilst pouring a stream of fresh life and interest into many of our secondary schools, they would involve no interference with any of the higher functions of our universities, no undue dissipation of energy, no lessening or lowering of their work as homes of learning and research. Such changes would, on the other hand, bring an extension and deepening of their influence in the general life of the people, making them more truly and more fully the universities of the nation, instinct with larger and more vigorous activities, and bringing them nearer than ever before in our day to the realisation of that ideal which a great English writer saw in his dreams when he said:

'A university is a place of concourse to which a thousand schools make contributions. She draws the world to her like ancient Athens, and sends out her literature, her preachers, her missionaries into the world.

'A university is a place which wins the admiration of the young by its celebrity, kindles the affection of the middle-aged by its beauty, and rivets the fidelity of the old by its associations. It is a seat of wisdom, a light of the world, a minister of the faith, an *alma mater* of the rising generation.'

So, with much more to the same effect, wrote John Henry Newman; and it is just because I desire to see our universities maintain and extend their marvellously fascinating and attractive influence as the nursing mothers of all that is best and most illuminating and most powerful in our national life that I press for the reforms I have ventured to advocate in this paper.

For convenience and clearness it may be well that I should briefly summarise the chief suggestions I have ventured to make.

A. *Examinations.*—1. The external examinations conducted by the universities would in many cases be better and more valuable if made more concrete and practical.

2. In the entrance examination to the university (Responsions or Little Go),

(*a*) Candidates should be free to offer some suitable equivalent in place of Greek.

(*b*) Some other much needed improvements should be introduced, *e.g.*—

(i.) An elementary knowledge of natural science and of one modern language should be made obligatory on all candidates.

(ii.) Ability to write English should be tested, and a knowledge of some period of English history and literature should be required.

(iii.) The examination in Latin or any other language should include questions on some period of history and literature, and on the subject matter of any prepared books, together with the translation of easy passages from authors that have not been prepared.

(iv.) Candidates should not be excluded from residence before passing this examination, nor should they be required to pass all subjects at the same time, but the passing in all the parts of this examination should be a necessary preliminary to entry for any other examination required for a degree.

(v.) It might reasonably be made a rule that no scholar should enjoy the emoluments of his scholarship until he had passed this examination.

(vi.) Marks of distinction should be given for work of superior merit in this and every other examination conducted by the university.

B. *Endowments.*—1. The value of open scholarships and exhibitions should be considerably reduced.

2. The money thus saved, or part of it, should be given in augmentation of scholarships held by poor students.

3. A fair proportion of scholarships should be awarded for excellence in a combination of subjects.

4. As a rule, no scholar should be allowed to receive any emolument till he had passed Responsions.

5. A percentage of the endowments now awarded as entrance scholarships (say 5 per cent. or more) should be distributed over the country as county scholarships on condition that the county raised an equivalent sum in each case; and a due share of these should be allotted to girls.

C. *Training of Teachers.*—1. There should be established in each university an Honour School or Tripos specially suited for those who are to take up the profession of teaching, and qualifying for the degree of B.A.

2. The establishment of such a school would carry with it the provision of adequate professorial and other instruction in the subjects required.

The Teaching of Science in Elementary Schools.—Report of the Committee, consisting of Dr. J. H. GLADSTONE (*Chairman*), Professor H. E. ARMSTRONG (*Secretary*), Lord AVEBURY, Professor W. R. DUNSTAN, Mr. GEORGE GLADSTONE, Sir PHILIP MAGNUS, Sir H. E. ROSCOE, Professor A. SMITHELLS, *and* Professor S. P. THOMPSON.

FOR a number of years past your Committee have given a tabular statement showing the increased attention which has been devoted to instruction in natural and experimental science from year to year. Up to 1890 the Government Code of regulations for day schools was so framed as practically to exclude such teaching. Schools were at that time limited to two so-called 'class subjects,' which were specifically defined as 'English, Geography, History, and Elementary Science,' and of which 'English' must be one. Of the other three 'Geography' has always been the most popular, and 'Elementary Science' was the least so. Hence, in the year 1889-90, the number of school departments in which English was taken amounted to no less than 20,304, while Elementary Science was taught in only 32. At that period the instruction in English was almost exclusively confined to grammatical exercises, and that in Geography to topographical details. Nowadays both terms are to be understood in a much broader and more scientific sense. At the period above named a free choice among these subjects was given, and the preponderance of English grammar began to decline, and has continued to do so ever since. In 1890-91 the figures for English and Elementary Science were 19,825 and 173 respectively; in 1891-92 they were 18,175 and 788; the table given below will show the comparative figures each succeeding year to 1899-1900. Object lessons were made an obligatory subject of instruction in the three lower Standards from September 1, 1896, and hence the rapid rise in the two succeeding years; they then became merged into the general term of Elementary Science, and, following the terminology of the Code, may sometimes be included under the head of Geography, which may account for the reduced numbers for Elementary Science in the last two years of the table:—

Class Subjects—Departments	1892-93	1893-94	1894-95	1895-96	1896-97	1897-98	1898-99	1899-1900
English . . .	17,394	17,082	16,280	15,327	14,286	13,456	13,194	12,993
Geography . .	14,256	15,250	15,702	16,171	16,646	17,049	17,872	18,632
Elementary Science	1,073	1,215	1,712	2,237	2,617	2,143	21,301	19,098
Object Lessons .	—	—	—	1,079	8,321	21,882		

A still greater change in these figures will probably become apparent next year, as the terms 'class subjects' and 'Elementary Science' are removed from the Code, and this branch of instruction is covered by the term of 'lessons, including object lessons, on Geography, History, and Common Things.' The number of departments in 'schools for older scholars' for the year 1899–1900 was 23,214, so that English Grammar, which ten years previously was taken almost universally, is now taken in little more than one-half of these; Elementary Science, mainly in the form of object lessons, being taken instead.

In last year's Report your Committee gave the number of scholars qualified for grants in specific subjects as compared with the number of scholars presented for examination in these several subjects in former years. It seemed to indicate that the abolition of the system of individual examination had been received with great favour by school managers and teachers, and that the work of the upper Standards had been more largely devoted to this branch of instruction. The returns for the year 1899–1900 appear to show that the spurt caused by the change in the plan of assessing the grant has not been fully maintained, every subject showing a falling-off as compared with the previous year, either absolutely, or relatively to the number of scholars in the upper Standards.

Specific Subjects	Scholars qualified for Grants	
	1898–99	1899–1900
Algebra	111,486	109,351
Euclid	5,932	6,208
Mensuration	24,848	24,432
Mechanics	50,324	42,534
Animal Physiology	41,244	36,810
Botany	8,833	8,905
Principles of Agriculture	1,163	1,166
Chemistry	14,737	13,557
Sound, Light, and Heat	1,943	1,733
Magnetism and Electricity	7,697	7,026
Domestic Economy	95,171	87,518
Totals	363,378	339,237

The figures for 1898–99 gave 50·7 as the percentage proportion of scholars qualified for grant as compared with the possible number of students. Those for 1899–1900 gave a percentage of only 45·1. It does not necessarily follow, however, that the ultimate result is to be regarded as unfavourable, for it appears that the amount of time given by the scholars individually during the year has been raised from about fifty-two to sixty hours.

The aggregate number of scholars in the Evening Continuation Schools taking subjects of instruction more or less scientific in their character has not varied much in the year 1899–1900 from that of the previous year's return, but is still considerably less than in 1897–98, as the following table will show. The fluctuation in the individual items is, however, larger than might have been expected from the close approximation of the totals, and would rather seem to indicate a want of continuity in the course of the studies.

Science Subjects	Number of Scholars			
	1896–97	1897–98	1898–99	1899–1900
Euclid	1,036	1,525	1,216	1,601
Algebra	7,467	9,996	7,432	7,247
Mensuration	27,388	29,966	24,369	23,090
Elementary Physiography	3,712	4,807	4,213	3,552
Elementary Physics and Chemistry	3,135	2,902	3,116	3,497
Domestic Science	....	117	142	471
Science of Common Things	10,910	13,874	11,499	11,418
Chemistry	5,658	6,590	5,963	6,704
Mechanics	1,365	1,129	987	1,252
Sound, Light, and Heat	726	813	437	305
Magnetism and Electricity	3,834	3,967	3,005	3,244
Human Physiology	5,865	6,237	4,296	4,619
Hygiene	3,179	4,062	3,276	3,228
Botany	692	763	597	718
Agriculture	2,355	2,300	1,826	1,847
Horticulture	1,001	1,354	1,350	1,511
Navigation	68	37	16	118
Ambulance	9,086	13,030	12,980	14,838
Domestic Economy	19,565	23,271	19,915	18,968
Totals	107,042	126,740	106,665	108,228

The alterations which have been made in this year's Code for England and Wales, beyond embodying last year's Minute establishing Higher Elementary Schools, consist mainly in the abolition of the schedules of instruction; teachers are thus left free to adopt whatever course of study they think best, or to follow more or less closely the specimen schemes which have been issued by the Board of Education for their guidance and which were referred to in last year's report. In the matter of Higher Elementary Schools very little progress has been made. The School Board for London and many of those in the larger provincial towns proposed to put their Higher Grade Schools under the Minute, but very few of their propositions have yet been approved by the Board of Education; the net result is that some half-dozen or so of schools which were recognised as Organised Science Schools under the Science and Art Department have been transferred to the Whitehall Board as Higher Elementary Schools, and are doing under the Minute very similar work to what they were doing before. Only one or two new schools have been opened as such. If the School Boards in England and Wales had the same freedom of adapting their schools to the special requirements of the locality that is enjoyed under the Scotch Code, many more of the Higher Grade Schools would ere this have been working under the Minute.

There has been considerable discussion between the School Board for London and the Board of Education as to the requirement by the latter of fully equipped Chemical and Physical Laboratories for the first and second years' scholars in these Higher Elementary Schools, as well as for those of the third and fourth years. To comply with the conditions of the Minute the children will have to be entered at about eleven years of age; and the School Board contends, and in this they are supported by the opinion of eminent authorities, that special laboratories and elaborate apparatus are not needed during the first two years, and that such would be harmful rather than otherwise. The School Board maintain that their proper function is to provide for these younger scholars practical

instruction in the rudiments of Science suited to their age and capacity, which can be illustrated by simple experiments in their ordinary class-room even better than in an expensive and highly organised laboratory.

Much difficulty is experienced by the School Board for London in obtaining teachers of experience. On this matter Lord Reay made the following remarks in his last annual address: 'The subject of the training of teachers is so important that I should not be justified if I did not allude to it. This Board has taken great care in providing better opportunities for training ex-pupil teachers and pupil teachers, and I trust that the increased facilities we asked for training our ex-pupil teachers for the Certificate Examination will be granted by the Board of Education. The Board had reason to believe that in too many cases the view of the teacher in giving a Science lesson was too exclusively confined to simply imparting isolated facts of Science to the scholars. It accordingly arranged courses of Pedagogical Lectures, confined to teachers capable of profiting by them, for the purpose of improving the methods of instruction in the practical teaching of Elementary Science. I believe that these lectures have already resulted in materially increasing the efficiency of the instruction, and that with the help of suggestions contained in the reports received from Dr. Kimmins, of the Technical Education Board, these lectures will be of increased value in still further improving the methods of Science instruction in schools of the Board.' The Board of Education at South Kensington have also arranged that 'a limited number of teachers and of students in Science classes under the Board who intend to become Science teachers are admitted free for a term or a session to the Sessional Courses of Instruction in the Royal College of Science.' The London School Board allow leave of absence to any of their teachers accepted for this course of instruction.

A Departmental Committee has been appointed to consider and report upon Training College Courses of Instruction. The principal term of the Reference was 'To draw up specimen Two-year Courses of Instruction for students in Training Colleges, with a view to ensuring that every student who leaves College shall have been through some course which shall prepare him in the best manner for some one or other of the various types of Elementary Schools.' The specimen schemes of instruction are still under the consideration of the Committee; but the Memorandum which has been already issued sets forth the general principles recommended by the Committee. The principal features are the liberty given to the Colleges to frame their own courses; the inclusion for the first time of Elementary Science and Manual Training; the minimising of examinations; and the association of the teachers with the examiners.

The Scotch Education Department has this year issued a Code of Regulations for Continuation Classes providing further instruction for those who have left school. This is to replace the former Evening Continuation School Code and the Science and Art Directory in so far as that related to evening classes. The chief novelty of this Code consists in the fact that the classes may be held at any time of the day. It is also interesting to note that there is no superior restriction of age. The work is arranged in four divisions. The first is apparently intended for the benefit of those whose early education has been somewhat neglected, and does not include any higher subjects than would be taken in an ordinary school—'the Principles of Arithmetic with such practical applications as may be approved of in any particular case, Geography and Nature Knowledge.' In Division II. the work begins to be specialised under different heads—

'(E.) Mathematics: Elementary Geometry, Algebra, Mensuration, Dynamics. (F.) Science: the Elementary Study, Theoretical or Practical, of Physical or Natural Science, or any branch thereof. (G.) Applied Mathematics and Science: (*a*) General: Practical Mathematics, including technical arithmetic and the use of mathematical instruments and tables; mechanical drawing; (*b*) Special: the application of Mathematics and Science to specific industries, Machine Construction, Building Construction, Naval Architecture, Electrical Industries, Mining, Navigation, Agriculture, Horticulture, or any other industry the scientific principles underlying which admit of systematic exposition. Where the nature of the subject requires it, previous or concurrent study of (G. *a*), or of the related branch of (E.) or of (F.) will be made a condition of taking any subject under (G. *b*). . . . By practical instruction is meant instruction under heads (F.) and (G.), which proceeds mainly by means of actual experimental work on the part of the pupils themselves in properly equipped laboratories or workshops, supplemented by the necessary explanations and demonstrations. Supplementary theoretical instruction may be reckoned as part of the practical course, but to an extent not exceeding one-half of the time occupied by the pupils in practical work.' In Division III. the work is of a more advanced character, and 'may either provide for graduated instruction in a single subject or for systematic instruction in a group of subjects, arranged with a view to fitting students for the intelligent practice of some particular industry or occupation.' A higher grant above that for the Commercial Courses is allowed for the Industrial Courses, subject to the condition 'that provision shall be made in properly equipped laboratories or workshops for such amount of practical work on the part of the students (being work illustrative of the principles taught, and not merely the practice of trade processes) as the Department may deem requisite in the particular circumstances.' Division IV. is concerned with auxiliary classes which do not come within the purview of this Committee.

The new Programme of Instruction for the National Schools of Ireland, which was issued in September 1900, abolished payment by results: the compulsory subjects of instruction were considerably changed, and the Commissioners of National Education indicated the methods of instruction they expected the teachers to adopt. It gave greater latitude to the teachers, both in the organisation of their schools and in the methods and amount of instruction given in them.

The following quotation from the Revised Regulations indicate the prominent position that has been accorded to Science Teaching in Irish Schools:—

'Elementary Science and Object Lessons are compulsory in schools in which there are teachers holding certificates of competency to give instruction in them, and these branches must be introduced into all schools as soon as possible.'

In view of the fact that little or no instruction in Science has been given for some years past in the schools, the Commissioners have appointed a Head Organiser for Science Instruction, whose duties are (*a*) to advise the Commissioners on matters relating to the introduction and development of Science Instruction, (*b*) to supervise the instruction of King's Scholars in the Training Colleges, (*c*) to arrange for the instruction in methods of Science Teaching of the teachers at present at work in the schools.

The extract from the 'Notes and Observations of the Commissioners,' which will be found in the Appendix, explains the purposes for which the

subject is introduced, and indicates the character of the teaching that is deemed desirable.

The problem of giving some training in the methods of Science Teaching to the 12,500 teachers in the National Schools is a very difficult one. It is further complicated by the fact that there are over three hundred large and well equipped convent schools conducted by nuns of various religious orders, who would naturally adopt the new subjects of instruction if they were properly trained; but in the majority of cases the nuns cannot leave the convents to attend the central classes for teachers.

Training centres have already been established and laboratories equipped in Dublin, Belfast, Cork, Londonderry, Waterford, and Limerick, and some five hundred male and female teachers have been taken through courses of training during the past year. These courses are of two kinds:—

(a) *Day courses*, at which the teacher attends every week-day for six weeks, spending about five hours per day in the laboratory.

(b) *Evening courses*, at which the teacher attends one or two evenings a week for a period of three hours each evening.

Travelling expenses and a small maintenance allowance are paid to teachers attending these courses. In addition to the laboratory work, each teacher is expected to produce a satisfactory written record of the practical work performed in the laboratory, and the certificate of competency to teach is not granted until a satisfactory notebook of the teacher's individual practical work is produced.

The course of work undertaken in these classes is based on the suggestions of the Committee of the British Association, and is similar in character to the old Course H of the English Code. Through this instruction endeavour is made to impress upon the teachers the importance of the method of scientific inquiry and of habits of accurate work, observation, reasoning, and expression; in the later stages of the work for Girls' Schools the science underlying domestic economy and hygiene is treated.

Of the six Training Colleges two give instruction to both men and women, two to women only, and two to men only; all have during the year provided themselves with laboratories for instruction in Experimental Science, and a most praiseworthy start has been made; thus nearly nine hundred students in training have received careful laboratory instruction. The average size of these Training College classes is thirty students. A new Training College for women, to be opened next session in Limerick, is also provided with an excellent laboratory.

The Commissioners have recently decided that the entire Inspection Staff is to undergo a course of training under the Head Organiser, in order to familiarise them with the methods the teachers are expected to pursue. A number of Inspectors are already attending these classes.

In order to facilitate the introduction of subjects of practical and manual instruction into schools in the poorer districts, the Treasury has sanctioned small grants of apparatus to these schools, on the condition that one of the teachers of the school has been through a satisfactory course of training.

The untimely death of the greatly esteemed Professor G. F. FitzGerald and the retirement from the Board of Commissioners of his Grace the Catholic Archbishop of Dublin (Dr. Walsh) are irreparable losses to the cause of true education in Ireland. To the efforts of these two distinguished educationists, both as members of the Commission on Manual and Practical Instruction and as Commissioners of National Education

the sweeping and far-reaching reforms in the Irish system of National Education are mainly due. It is impossible to overestimate the debt the country owes them.

Your Committee have not felt called upon to express an opinion on the important questions involved in the decision of the Court of King's Bench in the case of Rex *v.* Cockerton; but, whatever may be the final outcome of the present controversy, they trust that the interests of Science Teaching will not suffer, whatever the authority be to which it may be entrusted.

APPENDIX.

Irish National Schools.

'Object Lessons and Elementary Science.

'The Programme provides for alternative courses in Object Lessons and Elementary Science; but in most of the rural National Schools it would be desirable that the courses embracing the principles underlying Agriculture and Horticulture should be adopted. In this connection the Commissioners desire to direct the attention of Managers and Teachers to the French Scheme for teaching Agriculture, of which a translation is published in the Appendix to the Report of the Commission on Manual and Practical Instruction. At the same time the Commissioners leave Managers and Teachers free to select, with the concurrence of the Inspector, any of the courses that may seem most suited to the special circumstances of the schools. Managers may also submit for the approval of the Commissioners other courses than those provided, if they consider none of the Programme courses suitable.

'As regards Course I. of Elementary Experimental Science, it is intended that, as far as possible, all experiments should be performed by some, at any rate, of the scholars. The teaching should be directed, in the first place, to produce accurate habits of experiment, observation, and thought. The experiment should be undertaken with the object of solving a definite problem, and the explanation or discussion of results should not take place until the experiment has been repeated by individual members of the class a number of times. An accurate Balance is essential to such a course, and it should not be attempted without such an instrument. The greatest possible importance should be attached to the composition and style of the accounts of the experiment: these notes should represent the scholar's own version of the experiment. The primary purpose of such a course is to produce accurate habits of thought and work, and the mere giving of information should be subordinate to this purpose.

'In giving instruction in Object Lessons teachers should make a distinction between observation of the Object itself and giving information about the Object. The pupils in the first instance should be asked closely to oberve the Object, and to describe everything they can see or discover about it, before the teacher gives any instruction on the Object. In connection with Object Lessons and Elementary Science Lessons, as in connection with Manual and Practical Instruction, the Heuristic method should be continuously employed. The pupils should cultivate the habit of obtaining knowledge directly and at first hand, *finding out for them-*

selves, and thus developing the faculty of observation. Children should also be encouraged to make collections of Natural Objects to be found in the vicinity of the schools, and each school should have a Museum formed as far as possible from the collections of the pupils. Shells, stones, flowers, &c., would form most appropriate objects for a School Museum.

'A most useful combination of Drawing and Clay Modelling can be introduced as a help to the pupils in Object Lessons. Children should be encouraged to make simple drawings or models in clay of the simpler Objects. As with Drawing, the teacher should make frequent use of the blackboard in connection with Object Lessons.

'Where the circumstances are suitable, school excursions, to see Objects in their habitats, could be beneficially undertaken. Thus, a visit to the Zoological Gardens would enable the children to compare types of domestic animals with which they are familiar with wild animals of the same general order. In the same way periodical visits to a good kitchen garden would form an excellent series of Object Lessons of a real and useful character. While Object Lessons make the school lives of the children more happy, they also fulfil three principal and most important uses: they teach the children to observe, compare, and contrast; they impart information; and they form the basis for instruction in Drawing, &c.

'The courses in Elementary Science detailed in Section V. of Programme are not too difficult for the ordinary National School pupil. And here, again, the Commissioners think it necessary to remark that by the courses in Elementary Science they do not wish to train electricians, agriculturists, &c., but they wish to give all pupils useful instruction, and the possible future electrician or agriculturist such a knowledge of the great natural principles underlying his profession as will enable him to pursue it with success in after life.

'The great end teachers should endeavour to secure in connection with Elementary Science is to produce the scientific habit of research, and to impress the leading scientific principles upon the nascent intelligence by observation and simple experiment on the part of the pupils, and by plain expository and practical illustration on the part of the teacher.

'As a help to instruction in Course II., every school should, whenever possible, have a small plot of ground as a garden. If this is not feasible, garden boxes should be placed in the windows, and be planted with the simpler flowers, which could be used for illustrating the lessons. The gardens and boxes would, moreover, make the schools more cheerful and attractive to the children, and would aid largely in the development of artistic taste and a love of Nature.'

Corresponding Societies Committee.—Report of the Committee, consisting of Mr. W. WHITAKER (*Chairman*), Mr. T. V. HOLMES (*Secretary*), Professor R. MELDOLA, Mr. FRANCIS GALTON, Sir JOHN EVANS, Dr. J. G. GARSON, Mr. J. HOPKINSON, Professor T. G. BONNEY, *the late* Sir CUTHBERT PEEK, Dr. HORACE T. BROWN, Rev. J. O. BEVAN, Professor W. W. WATTS, Rev. T. R. R. STEBBING, Mr. C. H. READ, *and* Mr. F. W. RUDLER.

THE Corresponding Societies Committee have to report that in conformity with their resolution mentioned in the Report of last year notice was sent in March last to the Corresponding Societies inviting them to consider

what subjects they wish to have discussed at the Conference of Delegates at Glasgow. To this request only *one* Society, namely, the Hertfordshire Natural History and Field Club, responded, suggesting for the consideration by the Delegates 'The desirability of County Photographic Surveys.' As, however, the Delegate nominated by that Society afterwards found that he was unable to be present at Glasgow there was a subsequent request that the consideration of the subject be postponed. The Rev. J. O. Bevan's offer to bring before the Delegates the proposition 'That the Committees of the Corresponding Societies be invited to lay before their members the necessity of carrying on a systematic survey of their counties in respect to ethnology, ethnography, botany, meteorology, ornithology, archæology, folklore, &c.,' and Mr. C. H. Read's request to have an opportunity of introducing 'A plea for an Ordnance Map Index of Prehistoric Remains' were accepted as subjects for discussion at the Conference of Delegates at Glasgow, and notice of the same was sent by the Assistant General Secretary to the Delegates on receipt of their names from the Secretaries of their respective Societies. The question of copyright, which was a topic of discussion at the Conference of Delegates at Bradford last year, having been taken up by the Council of the Association, and they having authorised the General Officers of the Association to co-operate with other Societies in regard to the question if a Bill be again brought before Parliament, the Committee have taken no further action in the matter.

The Marine Biological Association of the West of Scotland and the Haslemere Microscope and Natural History Society were added to the list of Corresponding Societies. The Mining Association and Institute of Cornwall was removed from the list, it having ceased to publish.

Report of the Conference of Delegates of Corresponding Societies held at Glasgow, September 1901.

Mr. F. W. Rudler, F.G.S., Chairman, Mr. W. Whitaker, F.R.S., Vice-Chairman, and Dr. J. G. Garson and Mr. Alexander Somerville, Secretaries.

The Conferences were held on Thursday, September 12, and Tuesday, September 17, at 3 o'clock P.M., in the Medical Jurisprudence Class Room of the University, which was also open to Delegates to meet in at any time of the day during the meeting of the Association. Professor Glaister, moreover, was good enough to place his retiring room adjoining the class room at the disposal of the officers for meetings of Committee. For this indulgence the best thanks of the Committee are due to Professor Glaister. The following Corresponding Societies nominated Delegates to represent them at the Conferences. The attendance of Delegates at the Conferences is indicated by the figures 1 and 2 placed in the margin opposite each Society, the former figure referring to the first Conference, the latter to the second Conference. Where no figure is shown the Society will understand that its Delegate did not attend either of the Conferences, and that it was therefore not represented.

List of Societies sending Delegates.

		Andersonian Naturalists' Society	G. F. Scott-Elliot, M.A., B.Sc.
1	2	Belfast Naturalists' Field Club	William Gray, M.R.I.A.
1	2	Belfast Natural History and Philosophical Society	John Brown.

1		Birmingham and Midland Institute Scientific Society	C. J. Watson.
1	2	Birmingham Natural History and Philosophical Society	Alfred Browett.
		Buchan Field Club	J. F. Tocher, F.I.C.
1	2	Caradoc and Severn Valley Field Club	Professor W. W. Watts, F.G.S.
		Chesterfield and Midland Counties Institution of Engineers	Professor H. Louis, M.A.
	2	Croydon Microscopical and Natural History Club	W. Whitaker, F.R.S.
1	2	Dorset Natural History and Antiquarian Field Club	Vaughan Cornish, D.Sc., F.R.G.S.
1	2	East Kent Scientific and Natural History Society	A. S. Reid, M.A.
1	2	Essex Field Club	F. W. Rudler, F.G.S.
1		Glasgow Geological Society . .	J. Barclay Murdoch.
1		Glasgow Natural History Society .	A. Somerville.
		Glasgow Philosophical Society . .	Dr. Freeland Fergus.
		Hampshire Field Club and Archæological Society	Wm. Dale, F.S.A.
	2	Hertfordshire Natural History Society	W. Whitaker, F.R.S.
1	2	Holmesdale Natural History Club .	Miss Ethel Sargant.
1	2	Hull Geological Society . . .	G. W. Lamplugh, F.G.S.
1		Hull Scientific and Field Naturalists' Club	T. Sheppard, F.G.S.
		Institution of Mining Engineers. .	Professor Henry Louis, M.A.
1	2	Isle of Man Natural History and Antiquarian Society	P. M. C. Kermode.
1	2	Leeds Geological Association . .	Professor P. F. Kendall, F.G.S.
1	2	Liverpool Geographical Society . .	Staff-Com. Dubois Phillips, R.N.
1	2	Liverpool Geological Society . .	Joseph Lomas, F.G.S.
1	2	Malton Field Naturalists' and Scientific Society	M. B. Slater, F.L.S.
1		Manchester Geographical Society .	Eli Sowerbutts, F.R.G.S.
1		Manchester Microscopical Society .	F. W. Hembry, F.R.M.S.
1		Marine Biological Association of the West of Scotland	Dr. James Rankin.
1	2	Norfolk and Norwich Naturalists' Society	Francis D. Longe.
1	2	North of England Institute of Mining and Mechanical Engineers	J. H. Merivale, M.A.
1		North Staffordshire Field Club . .	R. Hornby, M.A.
		Northumberland, Durham, and Newcastle-upon-Tyne Natural History Society	Professor M. C. Potter, F.L.S.
1	2	Nottingham Naturalists' Society .	W. Bradshaw.
1	2	Paisley Philosophical Institution .	Andrew Henderson, LL.D.
1	2	Perthshire Society of Natural Science	Henry Coates, F.R.S.E.
		Rochdale Literary and Scientific Society	James Ogden.
1	2	Scotland, Mining Institute of . .	James Barrowman.
1	2	Warwickshire Naturalists' and Archæologists' Field Club	Wm. Andrews, F.G.S.
1	2	Woolhope Naturalists' Field Club .	Rev. J. O. Bevan, F.S.A.
1	2	Yorkshire Geological and Polytechnic Society	A. R. Dwerryhouse, F.G.S.
	2	Yorkshire Naturalists' Union . .	Harold Wager, F.L.S.

First Conference, September 12.

A Conference of the Delegates of the Corresponding Societies in connection with the British Association was held in the Medical Jurisprudence Lecture Theatre of the Glasgow University on Thursday, September 12, 1901, Mr. F. W. Rudler, F.G.S., Chairman, presiding.

The Corresponding Societies Committee were represented at the Conference by the Chairman, Mr. F. W. Rudler, the Secretary, Dr. J. G. Garson, the Rev. J. O. Bevan, and Professor W. W. Watts. The representatives of the Societies who attended will be seen from the list of Delegates.

The Chairman, in opening the proceedings, said:—If I may judge from the opinions which have been expressed at some former meetings, it will be the general desire of the Delegates, whom I have now the pleasure to welcome, that our present Conference shall be utilised for the discussion in a brief and business-like fashion of any suggestions which may be made for improving the work of our local Scientific Societies. No one mistakes this Conference for a supplementary Section of the Association: no one comes here, I hope, expecting to hear formal addresses and scientific papers such as he may hear and discuss at his own Society. But the prime object of these meetings, I take it, is to bring together representative members of various extra-metropolitan Societies, so that once a year at least they may have an opportunity of rubbing shoulder to shoulder; and, by social intercourse and a healthy exchange of ideas, may overcome any of the disadvantages which, in the case of the smaller provincial Societies, are likely to arise from insulation.

But although a formal address is not exacted from the Chair, yet I understand that some brief informal remarks by way of introduction to our work are not only usually tolerated, but have rather come to be expected. On this occasion it might perhaps be assumed that from my official connection with museum work I should take advantage of my position to say something about the relation of local Scientific Societies to local museums. That, however, is a subject which has already been dealt with at some of these meetings, notably at the Oxford Conference of 1894, when an interesting discussion on local museums—their origin, organisation, and maintenance—was initiated by the late Sir Cuthbert Peek. This name I cannot mention without adding an expression of personal regret at the loss which we have unexpectedly suffered. Sir Cuthbert was a member of the Corresponding Societies Committee, and a frequent attendant at these meetings; a man of very varied scientific interests, from whom, being in the prime of life, much good work might have been reasonably expected in the future.

In connection with museums it occurs to me that there is one unambitious piece of work which local Scientific Societies might readily and usefully undertake work which no doubt has been to some extent already accomplished, but which has rarely been carried out persistently and systematically. I refer to the *Registration of Type-specimens.* Every working naturalist from time to time finds himself confronted with the difficult task of tracing types and figured specimens. These are scattered far and wide over the country, often in provincial museums, sometimes in private collections, and occasionally coming to light in quarters where they would be least expected. Undoubtedly the best central treasure-house for all scientific specimens of exceptional interest is the British Museum, and the best thing to do with a type-specimen is to present it to that Museum. But in certain cases there will always be more or less objection to this course, and then the next best thing is obviously to place it in some provincial institution and let the scientific world know its whereabouts. No doubt this has already been done to a limited extent. Thus Committees of the British Association have been appointed to deal with particular groups of types, such as fossils; but

what I am anxious to urge is the importance of prosecuting the work in a systematic manner, and extending it to all departments of natural history.

So far as concerns the types which are preserved in provincial museums it may be said, probably, that the work should be done either by the museum itself or by that excellent institution, the Museums Association, an Association which has recently increased its usefulness by the issue of a monthly journal, which I may commend to the attention of local Societies. It is true that some of the larger museums have already published, or are now engaged in publishing, lists of their type-specimens, or at least certain classes of types. But most museums fail to possess the means of carrying out such work and properly publishing the results, and therefore could hardly resent the interference of a local Society. Moreover a museum could not be expected to take cognisance of specimens in private hands, whereas a Committee of the local Scientific Society could make it its business to seek out all the type specimens within its sphere of influence, whether in the local museum or in private collections, and could give permanence and publicity to the information thus acquired by printing the schedules of types in its proceedings.

The same kind of research might, in my opinion, be extended with advantage to local antiquities, at least to those of prehistoric age. Each Society might fitly publish lists of the antiquities which have been discovered within its own district, and which have been described and figured. Where the specimens remain in private hands, it is often difficult, and sometimes impossible, to trace them, but no one is likely to be more successful in the search than the members of the local Society. The advantage of knowing, when working at any particular subject, where the original specimens are located is so obvious that I venture to hope that the Delegates may see their way to urge the Societies which they respectively represent to move in the direction which I have indicated.

It seems to me doubtful whether it is desirable to suggest at this Conference many new lines of work to be taken up by our local Societies. In most cases they already possess programmes which are pretty heavily weighted, some Societies perhaps undertaking even more than they can satisfactorily accomplish ; and I believe it would probably be better in most cases to systematise and improve the existing work than to attempt the introduction of new departments of study. The governing body in each Society might well be charged with the duty of seeing that the work is worthy of the present position of science. The steady growth of scientific education in this country during recent years ought to tell most favourably upon the character of our local Societies. New members come prepared with a groundwork of scientific training unknown to most of the older members at the time they entered, and as a consequence the work of the Society should be lifted to a higher level than that on which we were formerly content to let it rest. It is satisfactory to note that in many cases this has been thoroughly realised, and indeed a review of the proceedings of the various local Societies at the present day shows that a high standard of excellence is often attained.

With regard to geology—the department of natural knowledge in which I happen to be specially interested—it is a matter of congratulation that so much good work should be accomplished by the several Societies which are in correspondence with the British Association. Not only are the local sections, the fossils, and the rocks receiving attention from those members who are interested respectively in stratigraphy, in palæontology,

and in petrology, but attention is being directed to the physiographic features of the district worked by the Society, or to that branch of inquiry which is nowadays known as geomorphology. In working out the history of the local topographic forms the geologist and the geographer join hands, and a grand field is opened up for just that kind of work which many members may take up with great advantage. On the fascinating subject of river development, for instance, I may point to recent papers by Mr. Buckman, read to the Cottswold Field Club, and by Mr. Paul to the Leicester Literary and Philosophical Society. Each local Society might well work out the history of the rivers in its own province, seeking to explain the whims of each stream, why it flows in this direction rather than in that, how it has flowed in the past, and how it may possibly flow in the future. Mr. Cowper Reed's recent Sedgwick Essay on the Rivers of East Yorkshire may be taken as an example of what may be done in this respect. In the modern view of river development, largely due to American geologists, the stream is regarded as working its way downwards, cutting its channel deeper and deeper, until it eventually reaches what Major Powell has called its 'base-level.' Then ceasing to work in this way, it meanders sluggishly over its plain, until an uplift is effected by some earth-movement, when a period of rejuvenescence sets in, and a new cycle of erosive activity is initiated. In a somewhat similar manner it may happen that a local Society, which in its youth was vigorous as a mountain stream, gradually finds its energy on the wane, and may at length reach a base-level of existence, when it flows placidly along, like the river in its lower reaches, very beautiful, and no doubt useful in its way, yet decidedly sluggish. But these annual meetings ought to act as elevatory agencies, restoring strength and revivifying the working powers. Let us hope, at any rate, that our present Conference may represent one of these periodical uplifts, and may be the means of starting some local Society upon a fresh career of healthy activity.

I ask you to pardon me for having trespassed upon your time by these prefatory remarks, and we shall pass now to the solid business which Dr. Garson has to bring before us. It appears that a circular was addressed on August 14 to the various Societies explaining that this meeting was to be held, and that a communication would be received from Mr. Read, the Keeper of British Antiquities in the British Museum, respecting an Index Map of Prehistoric Remains, but I fear he has not been able to attend the meeting. Secondly, there is a communication to be received from the Rev. J. O. Bevan, with a resolution to the effect that the Committees of the Corresponding Societies be invited to lay before their members the necessity of carrying on a systematic survey of their counties or districts in respect to ethnography, ethnology, meteorology, ornithology, &c. I am happy to say that Mr. Bevan is with us, and perhaps he will favour us with his communication.

Dr. Vaughan Cornish: On the matter of order, before proceeding to a fresh subject for the consideration of this Conference, I for one should like to know what has been done with reference to the communications brought before us last year, in which we were asked to do certain things which we were told would be of advantage to science. I should like to hear some report of the result of our efforts, and if it is not too late I should rather like to know what was the result of the communications and work which we did in the previous year; and I think some of us

will be interested also, although it is a matter of ancient history, to know the result of the efforts made in the year before that. These years cover the extent of my official connection with the Conferences, and on each of these occasions a learned gentleman has come before us and pointed out our shortcomings, and has urged us to fresh activities; but we have gone away, and what we have done or what other Delegates have done I for one do not know, because in the succeeding year there has been such a hurry to bring on the next proceedings that they have made no report of the last year's proceedings.

The Chairman: Personally I am very grateful to Dr. Cornish for bringing forward this subject, because it enables me to point out that though the bread which we cast upon the waters here may not always return to us, it may be carried elsewhere and feed some excellent Societies or other bodies with scientific pabulum. Last year a special communication was made by Professor Miall on the subject of Dew-ponds, and I took occasion on seeing him yesterday to inquire whether any work had been done following his suggestions. It was explained to me that he did not know that any Society had yet taken up the suggestions, but that he had, with some friends, been carrying on his investigations, and I believe that a person who gave him very great assistance in that direction in consequence of the subject having been brought before the last Conference was the Rev. Mr. Cornish, brother of Dr. Cornish, so that possibly Dr. Cornish himself could tell us what was done better than anyone else here. Something, therefore, has been accomplished, but the results have not been brought before the Association.

Dr. Cornish: We sometimes meet here and express doubts as to our usefulness. My impression is that we really have done a good deal of work in the last three years, but sufficient pains have not been taken to indicate the results from year to year; and I throw it out as a suggestion that at future Conferences the record of the past year should precede the reception of the paper in the next year.

Mr. Eli Sowerbutts: We sometimes have matters brought before us of no possible interest to us in the North, and it seems to be getting the habit to have long papers read to us, whether we want them or not. The difficulty lies in this, that there are no means of having communication between any of the Societies. We want these meetings to be of use to the British Association, but in a secondary way there is a vast amount of use which the Delegates' meetings may be to the various Societies scattered all over the kingdom; and we have great need for some meetings by which we could come more in contact. We are working in our little colonies here and there, and we think we are doing very well. Some man may be doing the same thing elsewhere under great discouragement, and if he could communicate with us, through the Secretary, I think that we might be able to help one another.

Dr. Garson: In order to allow us to get on with the business to-day, I may at once explain this matter by reminding the Delegates that at the Second Conference they are put in communication with the Secretaries of the various Committees appointed by the British Association each year, and it is from them that the Delegates or the Secretaries of Societies must receive and to whom they should give information as to what their Societies are able to do locally to further any investigation that a Committee of the Association is engaged on. What is actually done by the various Corresponding Societies, and the assistance which they have been

able to give, should be stated in the reports of the various Committees which appear in the Annual Report of the Association.

After a long discussion Captain Dubois Phillips (Liverpool) gave notice of a motion, to be brought forward at the next meeting, requesting that the Conference should receive each year a report on the outcome of the work of the previous year.

The Chairman then called on the Rev. J. O. Bevan to open the subject accepted of him by the Corresponding Societies Committee for discussion at this Conference: 'That the Committees of the Corresponding Societies be invited to lay before their Members the necessity of carrying on a systematic survey of their counties in respect to ethnology, ethnography, botany, meteorology, ornithology, archæology, folklore, &c.'

Mr. Bevan said:—

Looking at the number of Societies involved—at the facts that they are at work all the year round, collecting and assorting material—that a spirit of inquiry has been evoked as to the means by which a larger number of Societies could be knit to the General Association and a more complete co-ordination secured—it seems permissible to think that (with proper care and foresight) the Conference of Delegates bids fair to become as important an element of the British Association as any of the Sections; nay, more, that it may be developed so as to fulfil an independent function and to constitute the Association a General Clearing House of Science.

For some time past the Delegates have been inquiring at the annual meetings: 'What can we do—what can our Society do—to further the ends of science through the Association?'

Undeniably, the complete solution of this question will demand more thought and energy on the part of the Delegates, and on that of the Corresponding Societies Committee; but it need hardly be contended that if a thing be worth doing it is worth doing well, or that if a Conference of Delegates be run at all it should be run on business lines.

In all countries there is, and has long been going on, the preparation of more or less complete researches, and even the production of monographs dealing with all forms of nature and life—of archæology and history—of population and resources—of health and disease—and the like; but this has been usually without preliminary consultation and agreement between the several bodies engaged as to details of plan or scale. Consequently, the work is carried on without any unity as to the result, eventuating in greatly diminished usefulness and even intelligibility. Hence, the existence of general surveys—ordnance, geological, meteorological, botanical, anthropological, and archæological—in all stages of conjecture and incompleteness; but the interrelations of things, *e.g.*, of geology with geography—of flora and fauna with soil and climate—of territory with race and occupation, with national character and religious belief—have been suffered to remain unrecognised. Thus national, and especially international, comparison is rendered extremely difficult; in fact, no adequate comparison can be said to exist. One of the conclusions at which we arrive is that even the better monographic work of the past needs collation, rearrangement, and revision. The solution of the problem, however, is fairly in sight, viz., that of uniting all surveys into a regional survey, in which, as far as possible, all the classes of phenomena occurring in a specific region can be observed, recorded, and correlated with each other, so as to hinge together all the sequences of cause and effect.

In part, from its general character, the work must be carried out under Government sanction and authority, as in the case of the Geological, Ordnance, and Census Surveys. Again, the Society of Antiquaries has elaborated a scheme for the archæological survey of England and Wales. The work, however, progresses slowly, and does not touch Scotland or Ireland. Here at once is opened out a wide field of useful effort on the part of local Societies well within the compass of individual members—work as interesting as useful, lending itself, as it does, to literary, photographic, and artistic illustration. In this connection, moreover, the labours of the National Photographic Survey, under Sir J. B. Stone, may be indicated. But it is clear that investigation under more systematic lines is to be desiderated in respect of regional surveys throughout Great Britain and Ireland. This need was touched upon at the International Assembly in Paris in 1900, and circumstances at the Glasgow meeting of the British Association seem favourable for pressing the matter home. It is specifically alluded to in this paper, inasmuch as the subject is one in which the Corresponding Societies, without exception, would have an interest, and in which would be employed the energies of many members, each in his own sphere and in the exercise of his own special gift.

It is plain that unless the work is conducted and systematised through some central organisation, and tabulated on forms supplied or accepted by that organisation, a great part would be rendered useless or difficult of comparison.

The interchange of photographs and specimens would be a branch of the undertaking of great interest, and, besides, would contribute to an important object, viz., intercommunication between Societies of kindred aim.

It is hereby suggested that the Conference of Delegates should select one or more subjects of pressing interest, and undertake to bring before the respective Societies the advisability of undertaking systematic work (each in its own district) in these directions. These affiliated Societies, through their Delegates, would be expected to make a return of the results—partial or complete—at the ensuing meeting of the British Association.

In the choice of subjects three considerations (at least) present themselves :—

(*a*) They should be of a general kind, capable of being worked up by the local Societies in their respective districts.

(*b*) A preliminary arrangement should be arrived at whereby may be determined the lines and limits of investigation, the mode of tabulation of results, the scale of chart or map, the scheme of symbolical representation, coloration, nomenclature, conventional arrangement of detail, the method, form, size of publication, and the like.

(*c*) A special society or expert should be indicated as ready to advise in regard to each of the particular subjects.

The ends to be gained are these : The taking stock of all facts by a connected series of methodical surveys ; their registration before the corroding effect of time, the amalgamation of race, or any other cause, puts it beyond the reach of effort ; the full completion of surveys already begun ; the setting forth of results in a manner directly susceptible of useful comparison. A collateral advantage would be the discovery of a considerable amount of work already elaborated, and (with necessary revision and reduction to the common scale) its inclusion in the General Survey.

A beginning or an extension of past work might be made in respect of—

Meteorological and seismological phenomena.
Life zones.
Registration of type specimens.
Photographs of sections; records of well-borings, &c.
Phenomena of glaciation; erratic blocks.
Origin of lakes; changes of area and depth.
Coast and river erosion.
Pond, cavern, underground life.
Ethnographical, ethnological, archæological surveys.
Botanical survey to include fungi and algæ.
Phenological observations.

It will be understood that this list is provisional, but it is selected by reason of the fact that the field has been already entered upon, and that little further organisation is needed.

The Conference will make it clear that there is no intention to dictate to the various Societies involved. The suggestions are tentatively put forth in the interests of scientific research, and in response to the demand frequently made by Delegates. Each Society will consider the matter, and, in its wisdom, deal with the subject which seems the more nearly to come within its purview.

Certain objections may be forestalled:—

(*a*) 'Many Societies are composed of men possessing neither the inclination nor ability to take a share in a work of this kind, a few individuals constituting the leading spirits.' From such associations much will not be expected. Even in this case, however, the course suggested may act by way of stimulation, and these Societies are the ones which need to be waked up.

(*b*) 'The work is already done by our Society for its own neighbourhood.' Yes, but is it on the proper lines, and can it be brought forward for publication on the accepted system?

(*c*) 'A danger exists lest persons filled with enthusiasm, but otherwise imperfectly qualified for the task, should be incited to essay the task. This might lead to the production of results false and misleading.' But it is proposed that persons anxious to conduct any inquiry, or to co-operate therein, should be referred by the Committee of the Corresponding Society to a Society or individual expert in the work who would be in a position both to furnish direction and to check results.

I venture to move the resolution which stands in my name—'That the Committees of the Corresponding Societies be invited to lay before their members the necessity of carrying on a systematic survey of their counties or districts in respect of ethnography, ethnology, meteorology, ornithology, &c.'

Mr. Gray: I have very great pleasure in seconding the resolution. I think the communication which Mr. Bevan has read is one of the most valuable that we have had as crystallising our efforts and pointing out what we should really do. Anything in connection with the British Association must be done in an organised way. I have been a Delegate to this Conference from the Belfast Naturalists' Field Club for many years, and I do think that the Conference itself has acted like the river that the Chairman described. The Society I represent is an active Society. Of course we are composed of Irishmen, and necessarily active,

and we have done and desire to do good work. With the exception of Yorkshire, which has a number of organised Societies joined together, no one Society has done more than my own Society. No one has done more for archæology, and we have more material than any similar Society in Great Britain. I myself started many years ago with a systematic grouping of the ancient monuments of Antrim and Down, but our local work is not made generally useful for national purposes owing to the want of a proper systematic scheme, which should be formulated by a central authority like the British Association. It is perfectly useless for any local Society to start a system of its own, because that will be applied only locally, and we must adopt some systematised method. I therefore say that there should be an instruction to such a Society as ours as to the lines on which we should act. I understand that to be the object of this Conference, and I hope the suggestions will be taken so that we may act upon the lines laid down, and do very much more useful work, as might be done by the representatives at the Conference.

The Chairman: The resolution has been very ably moved and seconded, and it is now open for discussion.

Mr. F. D. Longe: I should like to know whether the British Association really means to take the initiative in suggesting to Societies what local work they should do. If the British Association will take the lead in that way I think that practical results will follow, but if it is left to the different Societies to take up what they like I think there will be endless discussion.

Dr. Garson: Every year the Secretary of the Corresponding Societies Committee sends a letter to the Recorder of each Section, intimating during the first week of the Meeting that the second Conference of the Delegates will be held on the following Tuesday, and requesting him to bring this fact before the Section of which he is Recorder, so that a representative from the various Committees appointed to do special work in connection with that Section may come here and explain to the Delegates what work they propose to do, and how the Corresponding Societies can assist these Committees.

Prof. J. H. Merivale: Mr. Bevan made a practical suggestion, which might be carried out, that we should have a social meeting—at least I think he meant a social meeting—each year. We had a meeting at Ipswich which was a great success. I think it would be a very excellent thing that we should have an opportunity of seeing one another and discussing matters in which we are mutually interested.

Mr. Gray: I am afraid that that suggestion does not come within the scope of the Association. I think that in Ireland, in accordance with our usual hospitality, we may take some steps to have you all together next year.

The Chairman: I should like to hear some remarks bearing directly on the subject which Mr. Bevan has so ably brought forward—remarks that would lead to something definite.

Captain Phillips: Although a systematic survey comes within the work of some of our Corresponding Societies I do not think it would come within that of all of them. For instance, my Society is a geographical Society, and the members of it are business men, who have their time fully taken up; in taking a survey such as is here contemplated in archæology you would find that my Society would be woefully in the dark. I shall, however, lay it before my Committee, but I do not think that I shall receive much encouragement, or that this meeting will receive much encouragement from my Society on this subject.

Mr. Alfred Browett: With the earlier portion of Mr. Bevan's remarks I must say that I feel most heartily with him, and it would be a great advantage if these remarks could be put on a leaflet and sent to the various Societies which we are here to represent. Speaking for my own Society, I think that we are largely in a state of ignorance as to what is expected of Delegates to this Association. I cannot help thinking that if a small leaflet were drawn up by the Committee of the Delegates we should have something to guide us, and efforts would be made to give effect to the suggestions that might be brought before us.

Mr. Gray: Might I call attention to the fact that the Annual Reports of the Association explain exactly what the relation of the various Societies is to the British Association, and that all the work that is done at these Conferences is brought, in the report, before the local Secretary of your Society, and it ought to be his duty to bring before the Council what is expected of you?

Dr. Vaughan Cornish: Do I understand that it is not the duty of the Delegate to bring these matters before the Society, but the duty of the Secretary of the Society? With whom does the function lie to bring it before the Society?

Dr. Garson: There is a copy of the Report of the Conferences of Delegates sent to the Delegate and also to the Secretary of each Society.

Dr. Vaughan Cornish: But whose duty is it?

Mr. Gray: It is the Secretary's duty to bring it before them when no Delegate from the Society has been appointed, and it is the duty of the Delegate to do so when there is one.

Mr. Sowerbutts: To make it secure that the Report of the Conferences is brought before the Societies it was resolved that the Committee be asked to send a report to the Secretary as well as to the Delegate.

Professor Merivale: I wish to suggest that the Societies might do what the North of England Institute of Mining and Mechanical Engineers have done with reference to geology. We have published sections of Northumberland and Durham. That is rather a large order, and the majority of the Societies, even if they should wish to do it, may not be in a position to do it. I throw it out as a suggestion to include geology more particularly to draw your attention to the immense amount of useful work that would be done by the publication of geological sections. We have six good-sized volumes, and they are invaluable to the mining engineer, at any rate, and to others in the district.

Professor Kendall: I think the suggestion is an admirable one, and I can see a way that the difficulty which Professor Merivale contemplates may be met. A Society which is poor can at least send reports to others which can be made available to all comers. It is appalling to think of the amount of geological information of priceless value which is utterly wasted year by year. Many well-sinkers take no trouble to record their work, and we only get very vague results. I think that if the local Societies would take up the matter and make persevering attempts to get into the confidence of the well-sinkers it might easily be done.

Mr. Henry Coates: Before the motion is put to the meeting I should like to make a suggestion; and it is this, that instead of coming to a formal resolution upon an important matter like this, it would perhaps clear the way if Mr. Bevan's paper were printed *in extenso* and copies sent to each of the Societies, and the Societies instructed to consider that paper fully during the coming session, and Delegates be instructed to

report upon the position taken up at our next Conference, because there is a great deal of detail in his paper that we have not heard to-day; and I think it would form very good subject-matter for the Societies to consider in detail, and then we would be in a better position to come to a resolution at our next Conference. It seems rather like taking an unfortunate time of the day when we have to come to a resolution without having considered the paper fully.

Professor Watts: I would suggest an amendment in order that the subject may be brought to an issue. I ought to say that I think anything in the way of systematising our work would be very important indeed; but I do not think we can expect any good from generalities. The Society that I represent—the Caradoc and Severn Valley Field Club—has a little volume called 'A Record of Bare Facts.' It is a very unambitious little work, but it nails down certain well known facts about the district. I should like to see a small Committee appointed to take up Mr. Bevan's paper and bring something before us at our next meeting in a definite form. I therefore propose that a small Committee, including Mr. Bevan, should be appointed to consider this subject and bring a definite statement which could be sent to the local Societies that we represent, with a suggestion to systematise work, because it is that kind of work that we practically want.

Professor Merivale: I beg to second Professor Watts' amendment.

On the amendment being put to the meeting, after much discussion, fifteen voted for the amendment and two against it.

The Chairman: Then the amendment is carried, and as a matter of form I propose to put it now as a substantive motion that this Committee be appointed. There is no one against it.

A Committee was then appointed, consisting of the Rev. J. O. Bevan, Mr. William Gray, Professor Watts, Professor Merivale, and Dr. Vaughan Cornish; Professor Watts to be convener.

Mr. Sowerbutts: Is there anything to report on the Conference as to the question of copyright? We went to a good deal of trouble and expense in gathering information to help us to see what the results of publishing the Societies' transactions when the proposals before the Committee of the House of Lords were carried out. I suppose it did go before the Committee of the Association at least, and we are anxious to know how it stands. We are given to understand that the Committee of the House of Lords is to be reappointed, and we should not be found asleep. It is of importance that the publication of a man's paper by us should not lose him the copyright. I sent a copy of the reports and of the correspondence to every Society, so that if the Delegates have not got it it is their own fault.

The Chairman: The Council of the Association has empowered the officers to co-operate with other scientific Societies for mutual protection if this Bill should be brought forward again, but at present it has lapsed.

The meeting was then adjourned.

Second Conference, September 17.

The Second Conference of Delegates of the Corresponding Societies of the British Association for the Advancement of Science was held on Tuesday, September 17, 1901, Mr. F. W. Rudler, F.G.S., Chairman of the Conference, presiding.

The Corresponding Societies Committee were represented by Mr. W. Whitaker, Mr. F. W. Rudler, Dr. J. G. Garson, the Rev. J. O. Bevan, and Professor W. W. Watts. The representatives of the Corresponding Societies present will be found in the list of Delegates.

The Chairman: It will be remembered that at our last meeting Captain Dubois Phillips gave notice of a motion which he would bring forward to-day, and I now call upon him to move it.

Captain Phillips: The resolution I have to propose is in the following terms: 'That the Corresponding Societies Committee be requested in future to bring before the Conference of Delegates some account of the outcome of the Conference of the preceding year.' 'Good wine needs no bush,' and I desist from making any remarks upon the resolution.

Dr. Vaughan Cornish: I rise to second the resolution moved by Captain Phillips, which was to some extent discussed at the last meeting. Any outcome of this resolution must entirely lie within the discretion of the Corresponding Societies Committee, and therefore I follow the example of Captain Phillips, and simply second that resolution without discussing its merits.

The Chairman: This motion has been moved by Captain Phillips and seconded by Dr. Cornish and the matter is open for discussion, but we discussed it so fully at the last meeting that I doubt whether it is reasonable to say much more on it now. We are all agreed upon it.

Mr. Whitaker: I am not going to discuss this resolution, as I have no doubt the Corresponding Societies Committee will fall in with it.

The resolution was then put and carried.

The Chairman: At our last meeting a small Committee of Delegates was appointed for the purpose of considering the suggestions brought forward by the Rev. Mr. Bevan; and Professor Watts, as convener of that Committee, will kindly bring up the report.

Professor Watts: Commendable brevity has been the keynote of this meeting so far, and I shall try to follow on the same lines. The Committee met and, endeavouring to act in accordance with the sense of the meeting so far as they could gather it, have drawn up the following recommendation which I shall read presently. In so doing they have endeavoured to avoid in any way dictating to the local Societies which have been doing good work along certain systematic lines, and we only wish to suggest that other Societies might take some part in this work. Some Societies may take up one branch and some another. The mere fact that these Societies are represented here is sufficient evidence that they are doing good work on their own account, so that no question arises on that score. There are certain subjects on which systematic work has been done, but that work is of comparatively little value because of its not being carried on all over the country. Now, although local Societies are doing a good deal of work, there are frequently members who are ready to take up new lines of work if these lines of work are suggested to them. The Committee have appended such a list, but they regard that list as merely provisional for this year, and they have avoided in most cases including subjects which will be brought before this Conference by the Delegates from the different sections. They would like to ask that this list should stand or fall as it is for this year, till it is seen how it works. If the matter is good, then the list can be added to or subtracted from, and in any case the work can be capitalised in that way. This is what the Committee recommend :—

The following provisional list of subjects, together with the names of some of the Societies which have already done work in connection therewith, and the names of persons who would be willing to receive communications thereon is recommended by the Conference of Delegates for adoption by the Corresponding Societies Committee of the British Association, and to be issued by them to the Corresponding Societies in the hope that those Societies not already engaged in similar work may take part in so much of it as comes within their scope, in order that the work may be extended over a wide area, and be done as far as possible upon a uniform system :—

'Registration of Type Specimens,' Dr. A. Smith Woodward.

'Coast Erosion,' Mr. W. Whitaker.

'Record of Bore Holes, Wells, and Sections,' North of England Institute of Mining and Mechanical Engineers, and Prof. J. H. Merivale.

'Tracing the Course of Underground Water,' Yorkshire Geological and Polytechnic Society, and Mr. A. R. Dwerryhouse.

'Erratic Blocks,' Yorkshire Naturalists' Union, and Professor P. F. Kendall.

'Geological Photographs,' Belfast Naturalists' Field Club, and Professor W. W. Watts.

'Underground Fauna,' Rev. T. R. R. Stebbing.

'Variations in the Course of Rivers and Shape of Lakes,' Dr. H. R. Mill.

'Archæological Survey by Counties,' Woolhope Field Club, and Rev. J. O. Bevan.

'Ethnographical Survey,' Anthropological Institute.

'Botanical Survey by Counties,' Mr. W. G. Smith.

'Photographic Record of Plants,' Mr. A. K. Coomara-Swamy.

I beg, then, to move that that report of the Committee be adopted.

Mr. Gray : I have pleasure in seconding the motion. As one who went over the list, any objections that I had have been effectively met by the report of the Committee.

The Chairman : This resolution has been moved by Professor Watts and seconded by Mr. Gray, and the subject is now open for discussion ; but I would venture to remark that as we have a great deal of work likely to come before us this afternoon, those Delegates who favour us with their views should do so as concisely as is consistent with clearness. That suggestion I am bold enough to make, not for the purpose of fettering discussion, but to avoid any undue prolongation of our sitting.

Captain Phillips : Since last meeting I have taken some pains on the subject of the suggestion brought before the meeting by the Rev. Mr. Bevan. I have written to Liverpool, and I find that most of the work that is spoken of, archæological, geological, and biological, has been taken up for years by the Societies there, and the work has been done and is all tabulated and charted. I think something might be done by this Conference getting into communication with the different Societies, and getting their work done so as to make a harmonious whole for the country, instead of having it only in detached groups.

On being put to the meeting the motion was unanimously agreed to.

The Chairman : I understand from Dr. Garson that we are favoured to-day with the presence of certain members from the various sections, and it is my duty to call upon those representatives to tell us whether they have anything to report or not.

SECTION A, MATHEMATICAL AND PHYSICAL SCIENCE.

The Chairman: The work of Section A includes Meteorology, which is a subject very largely taken up by the Corresponding Societies, and often discussed in these Conferences. As there does not seem to be any representative present, we pass to

SECTION B, CHEMISTRY.

Professor Herbert M'Leod: I should like to say on behalf of Section B that we have nominated a Committee to register the scientific chemists who are at work at different manufactories. Lately a great contrast has been drawn between the way that this country and Germany and other countries are using trained chemists in all their works, and we are seriously afraid that the numbers in this country are very small. The Committee was nominated by Section B to investigate this matter at the suggestion of Dr. Armstrong. It strikes me that it is not impossible that many of the members of this Conference might be able to assist in finding out the names of these people. It is not easy for persons living in London to send round to the different works and make inquiries when they may not know even of the existence of these works, and these gentlemen may not be able to assist.

I should like to refer to another subject which rather interests me at the present moment—I mean the tremendous number of scientific serials that exist. I do not say that they are not of the greatest possible value, but when I tell you that there are about 4,000 serials that have to be indexed for the International Catalogue, you may know the amount of time that is consumed in indexing them. I have in my hands the continuation of the Catalogue of scientific papers of the Royal Society from 1884 to 1900, and I cannot tell you the number of periodicals of which we have a list, but it must not be far short of 1,000. It is possible that these may contain papers of great value, and some must be of comparatively small value. We do not wish to catalogue any reprints or abstracts. I think that many members of this Conference might be of great assistance to us in telling us what would be advisable to index in their own periodicals, and if any of you will be good enough to write to me on the subject I shall be delighted. We begin at 1884, and we go up to 1900.

The Chairman: I understand that the representatives of the Sections are supposed to explain to the Delegates what work the Corresponding Societies can do to assist the various Committees that are appointed by the Sections. Then we come to

SECTION C, GEOLOGY.

Mr. A. S. Reid: I was asked to represent Section C. There has been no new Committee nominated in Section C, and there are only the old ones. The subjects which appeal to all the Societies are geological and photographic subjects, the registration of type specimens of fossils, and the movement of underground waters. The other subjects do not appeal to so many. The exploration of Irish caves does not naturally appeal to any of the English or Scotch clubs, and the study of the structure of crystals is more a matter for experts; but we have the subject of erratic blocks and their area. The Geological Photographic Committee has been doing certain new work during this term of office, which Professor Watts could explain.

Professor Watts: I am glad to take this opportunity of expressing how deeply grateful I am to the local Societies for the help they have given me during the time I have been Secretary of the Geological Photographic Committee. I should think that there are twenty Societies which have contributed photographs, often very valuable ones, and at least twelve Societies have done something or other towards making a photographic survey of their geological districts. If there are any gentlemen present at this Conference belonging to the counties at present unrepresented which I am going to mention, I hope they will see that their counties are no longer unrepresented. Rutland, Huntingdon, and Cambridge are the only counties in England which have not yet contributed. There are three Welsh counties and eleven Scotch counties and fourteen Irish counties. Amongst these counties are such interesting counties as Brecknock, Dumbarton, Ross-shire, Wicklow, Kilkenny, and Waterford, in all of which there is a lot of geological work to be done. I think I should make some slight allusion to the Publication Committee that has been formed in association with us. It was thought that there were a good many Societies which might like to have copies of photographs, and there have been made sixty or eighty or possibly a hundred sets of prints of interesting geological phenomena. Delays have unfortunately occurred, but still we are pushing on, and hope to complete the publication within the specified time. The set of photographs that should have been issued in 1900 is still unissued, but the prints are prepared, and the slides will very shortly be prepared, and I hope they will be issued to subscribers within a month.

Mr. Whitaker: I would like to add a word on this matter, referring not only to Section C, but to others. Unfortunately the grants were much cut down. An application was made for a grant for the geological photographs, and instead of obtaining 10*l.* it has fallen to 5*l.* I hope some means will be taken to make up the 5*l.*, because I am afraid if we do not Professor Watts will suffer in pocket, and that is not a thing that should be allowed. It is a splendid Committee and does magnificent work, and I have benefited very much by it, and through me others have benefited by it, but the absence of money is very unsatisfactory, and somehow or other we must try to get a little more funds.

The Chairman: We are greatly indebted to Professor Watts not only for giving this interesting explanation to the Conference, but also for the amount of labour he has spent upon this work. He is the life and spirit of the Committee, as we all know, and it is pleasing to hear that he has been so ably assisted by a large number of local Societies that are in correspondence with us.

Professor Kendall: I should like to put in a word about the grant for the erratic blocks. I had 6*l.* last year and spent it all and more than all. I thought that I would make a modest demand this year, and that if I asked for 10*l.* I should get 5*l.* I modestly asked for 5*l.* and got nothing at all. That is rather a hard case. The expense of the erratic blocks Committee is considerable. In the present year it is particularly unfortunate. In my report I am making an offer which will inevitably involve an expenditure of time, which we all expect, and of money, which we do not expect. Three years ago I visited Norway to study and collect specimens of the most characteristic rocks of Norway that we know to occur in the British group, and I have brought back about a ton of them. Last year I went and collected on a liberal scale the rocks on the

Cheviots with the same end, and in the present year I have sent sets of rocks to any local Society making application for such type rocks as are likely to occur in their districts. I made that reservation, because I do not see the use of supplying a South Welsh Society with Norwegian rocks, or of sending rocks from the Lake District to the North of Scotland. This involved me in a good deal of trouble and a good deal of expense, but I grudged neither the trouble nor the expense while the work was continued, but it is my experience that local Societies will just go as far as they are pushed, and directly we leave off pushing they stop. We have a magnificent record of erratics in the Liverpool district, but I am inclined to think that the local Societies there consider that they have reached an approximate finality in this work. We have also had records of the Pennine Chain through Lancashire and Yorkshire, but with these exceptions we have scarcely any records coming in at the present time. The Isle of Man was being done, also the North of Ireland under the very energetic guidance of the Belfast Naturalist Society, who have done very admirable work; but these are two bright spots over a very dull-looking map. In Scotland we have no erratics recorded at all. I sent a circular to every one of the Corresponding Societies, and I got a small number of responses; one response which came from Scotland gave me the assurance that the erratics in Scotland had been done, but I have failed to extract any useful or any considerable amount of useful information from the records, which relate largely to the position of boulders and other characteristics. I had only a few records from Ireland. The scope of this Committee has been enlarged deliberately at the request of the Committee itself, and I do hope that the Corresponding Societies of the British Isles will make a response, and if any locality will indicate anything in reason in the way of assistance I can give by means of specimens, &c., I shall be very pleased.

The Chairman: Professor Kendall has our sympathy in the unfortunate position in which he finds himself. We may now pass to

Section D, Zoology.

Mr. Denny: I am supposed to represent Section D. Just at the end of the business of the Committee I was asked to come here as a substitute, but I am not commissioned to bring anything before the Committee.

The Chairman: We next turn to

Section E, Geography.

Dr. Vaughan Cornish: I am delegated by Section E to bring before this Conference a new matter which has arisen at this meeting. You will have heard that there was a joint Conference of two or three Sections on the subject of Limnology, the study of lakes. This, of course, is a subject which can only appeal to a limited number of Societies—those in whose areas lakes occur—but it is hoped that these Societies which are fortunate enough to possess lakes in their districts will give their attention to this new proposal for the systematic study of the lakes of the British Isles. It is thought that the local Societies could assist in the early stages of that work, more particularly by collecting the bibliography or local publications relating to lakes; and if any of these references or publications of local Societies are sent to Sir John Murray he will be very glad indeed to receive them. Geography nowadays is becoming local in its character, or perhaps I should put it that the people of the British Isles are beginning

to turn their attention to the geography of their own country. I do not think a meeting of the British Association ever passes but that there are papers read which are distinctly local in their character. So far as the Glasgow meeting is concerned, I refer particularly to the papers which were read on Friday in Section E by Professor Scott Elliot on 'The Effects of Vegetation on the Valley and Plains of the Clyde'; the second by Dr. Marion Newbigin on 'Proposed Geographical Survey of the Valley of the Forth'; and the third by Professor W. G. Smith on 'A Botanical Survey of Scotland.' The authors of these papers will be glad to receive any assistance they can get from the local Societies, and I am directed generally to draw the attention of the Delegates to the meetings in Section E and to the discussion of local questions which occur there.

The Chairman: The subject of Limnology, which has received a great deal of attention on the Continent, has been ably dealt with in this country, especially by Dr. Mill; and I believe that Sir John Murray is to be associated with Mr. Lawrence Pullar in the survey of the British lakes about to be undertaken. If no one else wishes to speak on this matter, which has been fully discussed elsewhere, we will pass on to

Section F, Economic Science and Statistics.

This Section is apparently not represented, so we proceed to

Section G, Engineering.

Professor Dalby: I may state that we have two Committees at work at present, one of which has been sitting for about twenty years endeavouring to Standardise Small Screw Threads. Standards seem to be settled according to the caprice of the different makers; the Committee has consequently been endeavouring to bring into operation a universal standard; in fact, such a standard has been proposed and has been put into operation, and has been practically accepted in Paris; but as the difficulty in making a standard arises on account of the form of the thread, it is more a recommendation that has been made in order to obtain a simpler form of thread than has been done before. Any information on the point of screw-threads will be welcomed by the Committee.

The other Committee that I spoke of was only formed last year, and refers to a subject which may be interesting—I refer to Road Traction. A Committee was formed to find out how much it costs to pull a wheeled vehicle over different kinds of roads, and the Committee will be very glad to hear about the different kinds of roads in different districts in order that they may be included in the experiments. Of course the object of the experiments is not so much for horse-drawn vehicles as for motor-cars, and the investigation is to find out how much it costs to take these motor-cars over high roads. I hope we shall receive help on this question.

The Chairman: We are very much indebted to Professor Dalby for these remarks, and I hope that some Society will see its way to give assistance in these matters. We now come to

Section H, Anthropology.

Mr. H. Balfour: I was sent as representative of this Section to put before you some suggestions on the subject of collecting anthropological photographs. I was asked to state that any photographs and negatives

in the hands of the Committees of the Corresponding Societies, or individuals connected with those Societies, might be made more widely accessible to persons who are engaged in anthropology and archæology, if, after a a negative is finished with for the time being, it were deposited in some recognised centre, say the Anthropological Institute, and placed at the disposal of qualified people for use. In the case where the negatives are retained by their owners and not deposited as suggested, these might be registered in such a way that people may be able to find out what photographs have been taken, and whether they can be used for scientific purposes. That is one suggestion that I have to make, and I do not think it is necessary to enlarge on the subject. It has been already mooted in connection with other Sections, and I think it is obvious to all that it would be a very great convenience to those working at Anthropology.

Another suggestion that I should like to bring forward is that this Conference should draw the attention of the Corresponding Societies to the very great desirability of systematically collecting and recording instances of the survival of primitive customs, industries, appliances, and so forth. I am well aware that there is a great deal done in this direction, and I do not need to mention to you the enormous value which anthropology derives from survivals of primitive customs. Numbers of such survivals are still existing in our surroundings and only want recording. Many of these customs, of the very greatest interest to the student of primitive culture, are dying out at such a rapid rate that we should endeavour at once to record them as far as possible and photograph them if they are interesting. I hope that all the Corresponding Societies will be willing, on the suggestion of Section H, to bear this matter in mind. I would only mention or bring to your recollection that much of the very large amount of valuable work that General Pitt-Rivers did in his lifetime was due to his study of survivals. They will fill up the gaps in the archæological records in a way that these could not be filled up otherwise. I need say little about the importance of recording them, but I may make one remark. No one can have a higher admiration for the very noble institution known as the British Museum than I have, but at the same time I have a sort of uneasy feeling that it is representative of almost everything except British archæology and ethnology; and one object in raising this matter to-day is to suggest that this systematic collection of all such things as I have referred to should be made with a view to establishing some day a museum which will adequately represent the past history of our own country, not only the prehistoric period, but also the later mediæval and peasant life of the country which has not received sufficient attention so far. Every big town on the Continent, especially in the western part of it, has its Folk Museum, but we have nothing of the kind. Isolated attempts to deal with the matter in a somewhat simple manner are to be found, but nothing on any adequate scale. If it were possible to aim at the formation of a museum which would represent that side of culture, I think that we should have done a piece of work which will be well worth supporting.

Dr. Garson: In support of what Mr. Balfour has just said, I think I might refer to the last year's report, where it is stated that the Committee which he is representing wants photographs of prehistoric stone monuments, stone implements, primitive pottery, and all objects connected with local superstitions and the like. Objects of this kind are frequently to be found in local museums, and sometimes they are peculiar

to the locality only, but their existence is unknown very often except to a few people in the locality.

The Chairman : I can assure Mr. Balfour that we are fully sensible of our obligations to him for his very interesting remarks on this subject, which will probably give rise to discussion.

Rev. J. O. Bevan : I do not know that I have anything to say except about the anthropological map which I hope will be concluded very soon. As to the other subject that Mr. Balfour spoke about, the question of survivals, it is one that commends itself to the attention of the Delegates. Here in Scotland one ought to meet with a great many interesting samples, and anyone who has paid a visit to the local museums here will agree that they show very valuable material still available.

Mr. Reid : Might I ask the representative of Section H what one should do in the case of local dances ? I know of a dance that occurs in one of the islands in Scotland that is entirely unknown anywhere else. It is a kind of morris-dance, with a set of words that are handed down by father to son.

Mr. Balfour : One might obtain a surreptitious photograph of it. No doubt photographs would be worth getting of anything of that sort.

Dr. Garson : I may say that in connection with obtaining photographs of dances, &c., there is a camera, made by Watson, in the shape of an opera-glass, which photographs at right angles to the direction in which you appear to be looking. Probably by that apparatus some of those dances could be recorded.

After further remarks the Chairman passed to

Section K, Botany.

Mr. Harold Wager : I have been asked by the Committee of Section K to bring to your notice two new Committees which have been formed this year, in which the members of local Societies may be of great help. One of these is the Committee nominated to investigate the structure of blue-green algæ. The determination of the structure of these organisms is of great theoretical interest, and we shall be very glad if the Delegates would call the attention of their botanical members to the fact that specimens which may be obtained in various conditions will be extremely helpful in elucidating the important point of structure. If specimens can be sent to myself at Arnold House, Derby, we shall be very grateful. The other Committee is one which has been appointed to consider the desirability of collecting, preserving, and systematically registering photographs of botanical interest. We have been in communication with Professor Watts, and it is felt that botanical photographs, arranged on the same plan as the geological photographs are arranged, would be extremely helpful to us. A collection of photographs of rare plants growing in their natural habitats would be extremely valuable, and generally photographs would be a great help in systematically illustrating the characteristic formations of the various vegetation areas, such as moor, soft marsh, and so forth. Again, photographs of fungi, insects, plants as parasites and climbing plants, would be extremely interesting in a photographical botanical record. It is hoped that there may be a classification of these arranged on the same plan as has been found successful by the Geological Photographic Committee, and I would ask any botanical Society, if they have any

...ths to spare, to send them to Professor Weiss of Owens College, Manchester, who is the Secretary of the Committee. I have also to inform you that Professor Weiss will send out circulars to all natural history Societies communicating the wants of this Committee, and asking them to be good enough to help us as far as they can.

Mr. Whitaker : I am the representative here of a Society which does a certain amount of work, and our members would be delighted to help. I have seen many fine photographs of structure and abnormal growth, and photographs of special fungi collected at some of our meetings, and I have no doubt that other Societies will be in the same position. If Professor Weiss sends a circular to our Societies he will get something from them, and I am sure that they will endeavour to help him.

Mr. Coates : In our Perthshire Society, owing to the difficulty of preserving specimens of fungi, we have commenced making a complete series of photographs of all the fungi of the county. Our botanical members collect them and bring them to our rooms and the photographic members reproduce them. This might be found useful in other districts. We have them in our museum, and it would be quite easy to have duplicates made for other parties.

Mr. Wager : What we want is to have a botanical record.

Mr. Coates : I think many other Societies would be only too glad to do the same.

Professor Watts : I think it might be worth while to call the attention of any local Society taking this up to the fact that they might form a duplicate collection, each in its own locality. That has been done in some Societies in geological matters, and in this case it would be very important for the local Society to keep a set of prints in the locality. With regard to any other point, I should be only too delighted to give help to Professor Weiss in the details should this be satisfactory.

The Chairman : Botany is a department of natural knowledge that is so universally cultivated by local Societies that I hope the suggestions that Mr. Wager has favoured us with will bear much fruit. If no one else desires to address the Conference on Biology we shall pass to

Section L, Education.

Dr. Kimmins : I have been desired by this new Section to say that we have formed three Committees this year, but they are not on subjects which the Corresponding Societies could render any definite assistance. It is, however, very probable that in future years we will form Committees that will necessitate local investigations, and then we will appeal to you to help us.

Mr. Whitaker: The British Association has a remarkably good collection of the publications of local Societies. It is growing vastly, and as the space at the offices of the Association is limited it is a question as to what will be done with it in time. The great thing is to put it where it can be useful, and any suggestions on that subject would be welcome.

The Chairman : Has any other Delegate any other subject to bring forward? If not, I have to thank you very heartily for having attended on these two occasions, and we shall now adjourn until the next meeting of the British Association a year hence.

On the motion of Dr. Vaughan Cornish a hearty vote of thanks was given to the Chairman.

Full Title and Date of Foundation	Abbreviated Title	Address of Secretary				
Andersonian Naturalists' Society, 1885	Andersonian Nat. Soc.	204 George Street, Glasgow. R. Barnett Johnstone and R. McLean	211		2s. 6d.	Annals, occasionally.
Bath Natural History and Antiquarian Field Club, 1855	Bath N. H. A. F. C.	Rev. W. W. Martin, Royal Literary and Scientific Institution, Bath	100		10s.	Proceedings, annually.
Belfast Natural History and Philosophical Society, 1821	Belfast N. H. Phil. Soc.	Museum, College Square. R. M. Young, M.R I.A.	243		1l. 1s.	Report and Proceedings, annually.
Belfast Naturalists' Field Club, 1863	Belfast Nat. F. C.	Museum, College Square. William Gray and Dr. W. D. Donnan	330		5s.	Report and Proceedings, annually.
Berwickshire Naturalists' Club, 1831	Berwicksh. Nat. Club	G. G. Butler, M.A., Ewart Park, Wooler, Northumberland	400		7s. 6d.	History of the Berwickshire Naturalists' Club, annually.
Birmingham and Midland Institute Scientific Society, 1859	Birm. & Mid. Inst. Sci. Soc.	Alfred Cresswell, Birmingham and Midland Institute, Paradise Street, Birmingham	140		1l. 6s.	Records of Meteorological Observations, annually.
Birmingham Natural History and Philosophical Society, 1858	Birm. N. H. Phil. Soc.	Norwich Union Chambers Congreve Street, Birmingham. W.P.Marshall	199	None	1l. 1s.	Proceedings, annually.
Brighton and Hove Natural History and Philosophical Society, 1854	Brighton N. H. Phil. Soc.	E. A. Pankhurst, 3 Clifton Road, Brighton	170	10s.	10s.	Report, annually.
Bristol Naturalists' Society, 1862	Bristol Nat. Soc.	S. H. Reynolds, M.A., University College, Bristol	139	5s.	10s.	Proceedings, annually.
Buchan Field Club, 1887	Buchan F. C.	J. F. Tocher, F.I.C., 5 Chapel Street, Peterhead	170	5s.	5s.	Transactions, annually.
Burton-on-Trent Natural History and Archæological Society, 1876	Burt. N. H. Arch. Soc.	B. L. Oswell, 5 Balmoral Road, Burton-on-Trent	210	None	5s.	Annual Report. Transactions occasionally.
Caradoc and Severn Valley Field Club, 1893	Car. & Sev. Vall. F. C.	H. E. Forrest, 37 Castle Street, Shrewsbury	185	5s.	5s.	Transactions and Record of Rare Facts, annually.
Cardiff Naturalists' Society, 1867	Cardiff Nat. Soc.	Walter Cook, 98 St. Mary Street, Cardiff	480	None	15s.	Transactions, annually.
Chester Society of Natural Science, Literature, and Art, 1871	Chester Soc. Nat. Sci.	Grosvenor Museum, Chester. G. P. Miln and W. F. J. Shepheard	920	None	5s.	Report and Proceedings, annually.
Chesterfield and Midland Counties Institution of Engineers, 1871	Chesterf. Mid. Count. Inst.	Stephenson Memorial Hall. G. Alfred Lewis, Albert Street, Derby	360	1l. 1s. None	Members 31s. 6d.; Associates and Students 20s.	Transactions of Institution of Mining Engineers, monthly.
Cornwall, Royal Geological Society of, 1814	Cornw. R. Geol. Soc.	The Museum, Public Buildings, Penzance. John B. Cornish	95	None	1l. 1s.	Report and Transactions, annually.
Croydon Microscopical and Natural History Club, 1870	Croydon M. N. H. C.	Public Hall, Croydon. G. W. Moore	240	None	10s.	Proceedings and Transactions, annually.
Dorset Natural History and Antiquarian Field Club, 1875	Dorset N. H. A. F. C.	Nelson M. Richardson, Montevideo, Chickerel, Weymouth	330	None	10s.	Proceedings, annually.
Dublin Naturalists' Field Club, 1885	Dublin N. F. C.	C. J. Patten, M.D., Trinity College, Dublin	175	5s.	5s.	'Irish Naturalist,' monthly; Report, annually.
Dumfriesshire and Galloway Natural History and Antiquarian Society, 1862	Dum. Gal. N. H. A. Soc.	Dr. J. Maxwell Ross, St. Ruth's, Dumfries	205	2s. 6d.	5s.	Transactions and Journal of Proceedings, annually.
Eastbourne Natural History Society, 1867	Eastbourne N. H. Soc.	Dr. H. Habgood, Stafford House, Upperton Road, Eastbourne	102	2s. 6d	7s. 6d.	Transactions, annually.
East Kent Scientific and Natural History Society, 1857	E. Kent S. N. H. Soc.	A. Lander, The Medical Hall, Canterbury	102	None	10s.	Transactions, annually.
Edinburgh Geological Society, 1834	Edinb. Geol. Soc.	5 St. Andrew Square, Edinburgh. James Currie, F.R.S.E.	262	10s. 6d	12s. 6d.	Transactions, annually.
Essex Field Club, 1880	Essex F. C.	William Cole, Springfield, Epping New Road, Buckhurst Hill, Essex	300	None	15s.	'Essex Naturalist,' quarterly; 'Special Memoirs,' occasionally; 'Museum Handbooks.'

Full Title and Date of Foundation	Abbreviated Title	Head-quarters or Name and Address of Secretary	No. of Members	tran Fee	An... Subscri on	Title and Frequen Issue of Publicat
Glasgow, Geological Society of, 1858	Glasgow Geol. Soc.	J. Barclay Murdoch, Capelrig, Newton-Mearns, Glasgow	230	None	10s.	Transactions, annually.
Glasgow, Natural History Society of, 1851	Glasgow N. H. Soc.	J. J. Robertson, 207 Bath Street, Glasgow	344 Memb. and Assoc.	None	Members 7s. 6d. Associates 5s.	Transactions and Procee ings, annually.
Glasgow, Philosophical Society of, 1802	Glasgow Phil. Soc.	Peter Bennett, 207 Bath Street, Glasgow	950	1l. 1s.	1l. 1s.	Proceedings, annually.
Halifax Scientific Society, 1874	Halifax S. S.	Literary and Philosophical Society's Rooms, Harrison Road. F. Barker	190	None	2s. 6d.	'Halifax Naturalist,' eve two months.
Hampshire Field Club and Archæological Society, 1885	Hants F. C.	Hartley Institution, Southampton. W. Dale, F.G.S.	250	None	7s. 6d.	Proceedings, annually.
Haslemere Microscope and Natural History Society	Haslemere Mic. N. H. Soc.	Rev. G. B. Stallworthy, The Manse, Hindhead, Surrey	400	None	Minimum 2s.	Report, annually.
Hertfordshire Natural History Society and Field Club, 1875	Herts N. H. Soc.	A. E. Gibbs, F.L.S., St. Albans, and T. E. Lones, M.A., Rokeby Lodge, Watford	200	10s.	10s.	Transactions, three pa per annum.
Holmesdale Natural History Club, 1857	Holmesdale N. H. C.	Mrs. J. Lowell, Ivanhoe, Reigate; C. E. Salmon, Clevelands, Reigate	78	10s.	10s.	Proceedings, every two three years.
Hull Geological Society, 1887	Hull Geol. Soc.	W. S Parrish, 1 Waltham Street, Hull	71	None	5s.	Transactions, annually.
Hull Scientific and Field Naturalists' Club, 1886	Hull Sci. F. N. C.	T. Sheppard, F.G.S., 432 Holderness Road, Hull	173	None	4s.	Transactions, annually.
Institution of Mining Engineers	Inst. Min. Eng.	M. Walton Brown, Neville Hall, Newcastle-upon-Tyne	2,500	None	None	Transactions, monthly.
Inverness Scientific Society and Field Club, 1875	Inverness Sci. Soc.	E. G. Critchley, 29 High Street, Inverness	190	None	5s.	Transactions, occasional
Ireland, Statistical and Social Inquiry Society of, 1847	Stat. Soc. Ireland	J. Pim, W. Lawson, and C. H. Oldham, 35 Molesworth Street, Dublin	100	None	1l.	Journal, annually.
Leeds Geological Association, 1873	Leeds Geol. Assoc.	Philosophical Hall, Leeds. David Forsyth, M.A., D.Sc.	30	None	5s.	Transactions, occasional
Leeds Naturalists' Club and Scientific Association, 1868	Leeds Nat. C. Sci. Assoc.	J. H. Gough, F.C.S., 14 Francis Street, Chapeltown Road, Leeds	118	None	5s.	Transactions, occasional
Leicester Literary and Philosophical Society, 1835	Leicester Lit. Phil. Soc.	Corporation Museum. Herbert Ellis	328 Membs. & Associates	None	Members 1l. 1s.; Associates 10s. 6d.	Transactions, quarterly.
Liverpool Engineering Society, 1875	Liverpool E. Soc.	R. C. F. Annett, 4 Buckingham Avenue, Sefton Park, Liverpool	518	None	Resident 1l. 1s. Non-Res. and Students 10s. 6d.	Transactions, annually.
Liverpool Geographical Society, 1891	Liverpool Geog. Soc.	Capt. E. C. Dubois Phillips, R.N., 14 Hargreave's Buildings, Chapel Street, Liverpool	730	None	Members 1l. 1s. Associates 10s. 6d.	Transactions and Rep annually.
Liverpool Geological Society, 1858	Liverpool Geol. Soc.	Royal Institution. H. C. Beasley	50	None	21s.	Proceedings, annually.
Liverpool, Literary and Philosophical Society of, 1812	Liverpool Lit. Phil. Soc.	Royal Institution. J. Maxwell McMaster	214	None	1l. 1s.: Ladies 10s. 6d.	Proceedings, annually.
Malton Field Naturalists' and Scientific Society, 1879	Malton F. N. Sci. Soc.	Rev. F. J. R. Young, 95 Wold Road, Norton Malton, Yorks.	121	None	5s. and 2s. 6d.	Report, occasionally.
Man, Isle of, Natural History and Antiquarian Society, 1879	I. of Man N. H. A. Soc.	P. M. C. Kermode, Croll-ny-Feeney, Ramsey, Isle of Man	158	2s. 6	Gentlemen 7s. 6d. Ladies and Non Residents 5s.	Yn Lioar Manninagh, biennially.
Manchester Geographical Society, 1884	Manch. Geog. Soc.	Eli Sowerbutts, F.R.G.S., 16 St. Mary's Parsonage, Manchester	800	None	Members 1l. 1s.; Associates 10s. 6	Journal, quarterly; 'C graphy,' monthly.
Manchester Geological Society, 1838	Manch. Geol. Soc.	5 John Dalton Street, Manchester. W. Saint and J. Tonge, jun.	233	None	1l.	Transactions, monthly.
Manchester Microscopical Society, 1880	Manch. Mic. Soc.	E. C. Stump, 16 Herbert Street, Moss Side, Manchester	195	5s.	.	Transactions and Rep annually.
Manchester Statistical Society, 1833	Manch. Stat. Soc.	63 Brown Street, Manchester. F. E.	235		5d.	Transactions, annually.

tory Society, 1864		a. rlborough College. E. Meyrick		. . 6d.		Report, annu...
Midland Institute of Mining, Civil, and Mechanical Engineers, 1869	Midland Inst. Eng.	T. W. H. Mitchell, Mining Offices, Regent Street, Barnsley		None	. 10s.	Transactions of Institution of Mining Engineers, monthly.
Norfolk and Norwich Naturalists' Society, 1869	Norf. Norw. Nat. Soc.	W. A. Nicholson, St. Helen's Square, Norwich		None	5s.	Transactions, annually.
North of England Institute of Mining and Mechanical Engineers, 1852	N. Eng. Inst.	M. Walton Brown, Neville Hall, Newcastle-upon-Tyne	1,250	No	and 2s.	Trans. of Institution of Mining Engineers, monthly.
North Staffordshire Field Club	N. Staff. F. C.	Rev. T. W. Daltry, M.A., Madeley Vicarage, Newcastle, Staffs; W. Wells Bladen, Stone, Staffs	461	5s.	5s.	Report and Transactions, annually.
Northamptonshire Natural History Society and Field Club, 1876	N'ton. N. H. Soc.	H. N. Dixon, M.A., 23 East Park Parade, Northampton	180	None	10s.	Jo nal, quarterly.
orthumberland, Durh m a d Newcastle-u on-Tyne, Natural History Society of	Northumb. N. H. Soc.	Hancock Museum, Newcastle-on-Tyne. A. H ... and Prof. C. M. Potter	300	None	1s.	Tr nsactions, annually.
Nottingham Naturalists' Society, 1852	Nott. Nat. Soc.	Prof. J. W. Carr, M.A., University College, Nottingham	150	2s. 6d.	5s.	Report, annually.
Paisley Philosophical Institution, 1808	Paisley Phil. Inst.	J. Gardner, 3 County Place, Paisley	409	5s.	. 6d.	Report, annually; Meteorological Obs., occasionally.
Penzance Natural History and Antiquarian Society, 1839	Penz. N. H. A. Soc.	Museum, Public Buildings, Penzance. J. B. Cornish	67	None	s. 6d	Report, annually; Transactions, occasionally.
Perthshire Society of Natural Science, 1867	Perths. Soc. N. Sci.	Tay Street, Perth. S. T. Ellison	3 0	2s. 6d.	. 6d.	Transactions and Proceedings, annually.
Rochdale Literary and Scientific Society, 1878	Rochdale Lit. Sci. Soc.	J. Reginald Ashworth, B.Sc., 105 Freehold Street, Rochdale	245	None	6s.	Transactions, biennially.
Rochester Naturalists' Club, 1878	Rochester N. C.	John Hepworth, Linden House, Rochester	115	None	5s.	'Rochester Naturalist,' quarterly.
Scotland, Mining Institute of, 1878	Mining Inst. Scot.	James Barrowman, Staneacre, Hamilton, N.B.	449	None	and 5s.	Trans. Institution of Mining Engineers, monthly.
Somersetshire Archæological and Natural History Society, 1848	Som'setsh. A. N. H. Soc.	The Castle, Taunton. Lt.-Col. J. R. Bramble and Rev. F. W. Weaver	611	10s. 6d.	s. 6d.	Proceedings, annually.
South African Philosophical Society, 1877	S. African Phil. Soc.	G. S. Corstorphine, South African Museum, Cape Town	132	None	2l.	Transactions, occasionally.
South-Eastern Union of Scientific Societies, 1896	S.-E. Union	George Abbott, M.R.C.S., 33 Upper Grosvenor Road, Tunbridge Wells	35 Socie	None	.	'South-Eastern Naturalist,' annually.
South Staffordshire and East Worcestershire Institute of Mining Engineers, 1867	S. Staff. Inst. Eng.	Alexander Smith, M.Inst.C.E., 3 Newhall Street, Birmingham	178	. 1s. 0 / 10s. 6d	nd	Transactions of Institution of Mining Engineers, monthly.
Toronto, Astronomical Society of, 1884	Toronto Astr. Soc.	Canadian Institute Building. W. B. Musson	125	None	ars	Transactions, annually.
Tyneside Geographical Society 1887	Tyneside Geog. Soc.	Geographical Institute, Barras Bridge, Newcastle-on-Tyne. Herbert Shaw, B.A.	1,200	None	d	Journal annually.
Warwickshire Naturalists' and Archæologists' Field Club, 1854	Warw. N. A. F. C.	Museum, Warwick. C. West, 31 Cherry Street, Coventry	109	2s. 6d.	5s.	Proceedings, annually.
West of Scotland Marine Biological Association of the	W. Scot. Marine Biol. Assoc.	John A. Todd, 190 West George Street, Glasgow	140	None	inimu 1l. 1s.	Communications, irregularly.
Woolhope Naturalists' Field Club, 1851	Woolhope N. F. C.	Woolhope Club Room, Free Library, Hereford. H. Cecil Moor	240	10s.	10s.	Transactions, biennially.
Yorkshire Geological and Polytechnic Society, 1837	Yorks. Geol. Poly. Soc.	Rev. Wm. Lower Carter, M.A. F.G.S., Hopton, Mirfield	180	None	13s.	Proceedings, annually.
Yorkshire Naturalists' Union, 1861	Yorks. Nat. Union	W. Denison Roebuck, F.L.S., Hyde Park Road, Leeds Hawkesworth, Hunslet, Leed	425 and 2,6 Associat	None	0s. 6	Transactions, annually; 'The Naturalist,' monthly.
Yor hical 18		Museum, York. Dr. Tempest A on and C. E. Elmhirst	400			Report, annually.

Catalogue of the more important Papers, and especially those referring to Local Scientific Investigations, published by the Corresponding Societies during the year ending June 1, 1901.

*** This catalogue contains only the titles of papers published in the volumes or parts of the publications of the Corresponding Societies sent to the Secretary of the Committee in accordance with Rule 2.

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TRANSACTIONS OF THE SECTIONS.

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Section A.—MATHEMATICAL AND PHYSICAL SCIENCE.

President of the Section.—Major P. A. MacMahon, D.Sc., F.R.S.

THURSDAY, SEPTEMBER 12.

The President delivered the following Address:—

During the seventy meetings of the Association a pure mathematician has been president of Section A on ten or a dozen occasions. A theme taken by many has been a defence of the study of pure mathematics. I take Cayley's view expressed before the whole Association at Southport in 1883 that no defence is necessary, but were it otherwise I feel that nothing need be added to the eloquent words of Sylvester in 1869 and of Forsyth in 1897. I intend therefore to make some remarks on several matters which may be interesting to the Section even at the risk of being considered unduly desultory.

Before commencing I must remark that during the twelve months that have elapsed since the Bradford Meeting we have lost several great men whose lives were devoted to the subjects of this Section. Hermite, the veteran mathematician of France, has left behind him a splendid record of purely scientific work. His name will be always connected with the Herculean achievement of solving the general quintic equation by means of elliptic modular functions. Other work, if less striking, is equally of the highest order, and his treatise 'Cours d'Analyse' is a model of style. Of FitzGerald of Dublin it is not easy to speak in this room without emotion. For many years he was the life and soul of this Section. His enthusiasm in regard to all branches of molecular physics, the force and profundity of his speech, the vigour of his advocacy of particular theories, the acute thinking which enabled him to formulate desiderata, his warm interest in the work of others, and the unselfish aid he was so willing to give, are fresh in our remembrance. Rowland was in the forefront of the ranks of physicists. His death at a comparatively early age terminates the important series of discoveries which were proclaimed from his laboratory in the Johns Hopkins University at Baltimore. In Viriamu Jones we have lost an assiduous worker at physics whose valuable contributions to knowledge indicated his power to do much more for science. In Tait, Scotland possessed a powerful and original investigator. The extent and variety of his papers are alike remarkable, and in his collected works there exists an imperishable monument to his fame.

It is interesting, in this the first year of the new century, to take a rapid glance at the position that mathematicians of this country held amongst mathematicians a hundred years ago. During the greater part of the eighteenth century the study of mathematics in England, Scotland and Ireland had been at a very low ebb. Whereas in 1801 on the Continent there were the leaders Lagrange, Laplace and Legendre, and of rising men, Fourier, Ampère, Poisson and Gauss, we

could only claim Thomas Young and Ivory as men who were doing notable work in research. Amongst schoolboys of various ages we note Fresnel, Bessel, Cauchy, Chasles, Lamé, Möbius, v. Staudt and Steiner on the Continent, and Babbage, Peacock, John Herschel, Henry ParrHamilton and George Green in this country. It was not indeed till about 1845 or a little later that we could point to the great names of William Rowan Hamilton, MacCullagh, Adams, Boole, Salmon, Stokes, Sylvester, Cayley, William Thomson, H. J. S. Smith and Clerk Maxwell as adequate representatives of mathematical science. It is worthy of note that this date, 1845, marks also the year of the dissolution of a very interesting society, the Mathematical Society of Spitalfields; and I would like to pause a moment and, if I may say so, rescue it from the oblivion which seems to threaten it. In 1801 it was already a venerable institution, having been founded by Joseph Middleton, a writer of mathematical text-books, in 1717.[1] The members of the Society at the beginning were for the most part silk-weavers of French extraction; it was little more than a working man's club at which questions of mathematics and natural philosophy were discussed every Saturday evening. The number of members was limited to the 'square of seven,' but later it was increased to the 'square of eight,' and later still to the 'square of nine.' In 1725 the place of meeting was changed from the Monmouth's Head to the White Horse in Wheeler Street, and in 1735 to the Ben Jonson's Head in Pelham Street. The subscription was six-and-sixpence a quarter, or sixpence a week, and entrance was gained by production of a metal ticket which had the proposition of Pythagoras engraved on one side and a sighted quadrant with level on the other. The funds, largely augmented by an elaborate system of fines, were chiefly used for the purchase of books and physical apparatus. A president, treasurer, inspector of instruments and secretary were appointed annually, and there were, besides, four stewards, six auditors, and six trustees. By the constitution of the Society it was the duty of every member, if he were asked any mathematical or philosophical question by another member, to instruct him to the best of his ability. It was the custom for each member in rotation to lecture or perform experiments at each evening meeting. There was a fine of half-a-crown for introducing controverted points of divinity or politics. The members dined together twice annually, viz., on the second Friday in January in London in commemoration of the birth of Sir Isaac Newton (this feast frequently took place at the Black Swan, Brown's Lane, Spitalfields), and on the second Friday in July 'at a convenient distance in the country in commemoration of the birth of the founder.' The second dinner frequently fell through because the members could not agree as to the locality. It was found necessary to introduce a rule fining members sixpence for letting off fireworks in the place of meeting. Every member present was entitled to a pint of beer at the common expense, and, further, every five members were entitled to call for a quart for consumption at the meeting. Such were some of the quaint regulations in force when, about the year 1750, the Society moved to larger apartments in Crispin Street, where it remained without interruption till 1843. It appears from the old minute books that about the year 1750 the Society absorbed a small mathematical society which used to meet at the Black Swan, Brown's Lane, above mentioned, and that in 1783 an ancient historical society was also incorporated with it. By the year 1800 the class of the members had become improved, and we find some well-known names, such as Dolland, Simpson, Saunderson, Crossley, Paroissen and Gompertz. At this time lectures were given in all branches of science by the members in the Society's rooms, which on these occasions were open to the public on payment of one shilling. The arrangements for the session 1822–23 included lectures in mechanics, hydrostatics and hydraulics, pneumatics, optics, astronomy, chemistry, electricity, galvanism, magnetism

[1] Its first place of meeting was the Monmouth's Head, Monmouth Street, Spitalfields. This street has long disappeared. From a map of London of 1746 it appears to have run parallel to the present Brick Lane and to have corresponded to the present Wilks Street.

and botany, illustrated by experiments. On account of these lectures the Society had to fight an action-at-law, and although the case was won, its slender resources were crippled for many years. In 1827 Benjamin Gompertz, F.R.S., succeeded to the presidency on the death of the Rev. George Paroissen. From the year 1830 onwards the membership gradually declined and the financial outlook became serious. In 1843 there was a crisis; the Society left Crispin Street for cheaper rooms at 9 Devonshire Street, Bishopsgate Street, and finally, in 1845, after a futile negotiation with the London Institution, it was taken over by the Royal Astronomical Society, which had been founded in 1821. The library and documents were accepted and the few surviving members were made life members of the Astronomical Society without payment. So perished this curious old institution; it had amassed a really valuable library, containing books on all branches of science. The Astronomical Society has retained the greater part, but some have found their way to the libraries of the Chemical and other societies. An inspection of the documents establishes that it was mainly a society devoted to physics, chemistry and natural history. It had an extensive museum of curiosities and specimens of natu-al history, presented by individual members, which seems to have disappeared when the rooms in Crispin Street were vacated. It seems a pity that more effort was not made to keep the old institution alive. The fact is that at that date the Royal Society had no sympathy with special societies and did all in its power to discourage them. The Astronomical Society was only formed in 1821 in the teeth of the opposition of the Royal Society.

Reverting now to the date 1845, it may be said that from this period to 1866 much good work emanated from this country, but no Mathematical Society existed in London. At the latter date the present Society was formed, with De Morgan as its first President. Gompertz was an original member, and the only person who belonged to both the old and new societies. The thirty-three volumes of proceedings that have appeared give a fair indication of the nature of the mathematical work that has issued from the pens of our countrymen. All will admit that it is the duty of anyone engaged in a particular line of research to keep himself abreast of discoveries, inventions, methods, and ideas, which are being brought forward in that line in his own and other countries. In pure science this is easier of accomplishment by the individual worker than in the case of applied science. In pure mathematics the stately edifice of the Theory of Functions has, during the latter part of the century which has expired, been slowly rising from its foundations on the continent of Europe. It had reached a considerable height and presented an imposing appearance before it attracted more than superficial notice in this country and in America. It is satisfactory to note that during recent years much of the leeway has been made up. English-speaking mathematicians have introduced the first notions into elementary text-books; they have written advanced treatises on the whole subject; they have encouraged the younger men to attend courses of lectures in foreign universities; so that to-day the best students in our universities can attend courses at home given by competent persons, and have the opportunity of acquiring adequate knowledge, and of themselves contributing to the general advance. The Theory of Functions, being concerned with the functions that satisfy differential equations, has attracted particularly the attention of those whose bent seemed to be towards applied mathematics and mathematical physics, and there is no doubt, in analogy with the work of Poincaré in celestial dynamics, those sciences will ultimately derive great benefit from the new study. If, on the other hand, one were asked to specify a department of pure mathematics which has been treated somewhat coldly in this country during the last quarter of the last century, one could point to geometry in general, and to pure geometry, descriptive geometry, and the theory of surfaces in particular. This may doubtless be explained by the circumstance that, at the present time, the theory of differential equations and the problems that present themselves in their discussion are of such commanding importance from the point of view of the general advance of mathematical science that those subjects naturally prove to be most attractive.

As regards organisation and co-operation in mathematics, Germany, I believe,

stands first. The custom of offering prizes for the solutions of definite problems which are necessary to the general advance obtains more in Germany and in France than here, where, I believe, the Adams Prize stands alone. The idea has an indirect value in pointing out some of the more pressing desiderata to young and enthusiastic students, and a direct importance in frequently, as it proves, producing remarkable dissertations on the proposed questions. The field is so vast that any comprehensive scheme of co-operation is scarcely possible, though much more might be done with advantage.

If we turn our eyes to the world of astronomy we find there a grand scheme of co-operation which other departments may indeed envy. The gravitation formula has been recognised from the time of Newton as ruling the dynamics of the heavens, and the exact agreement of the facts derived from observation with the simple theory has established astronomy as the most exact of all the departments of applied science. Men who devote themselves to science are actuated either by a pure love of truth or because they desire to apply natural knowledge to the benefit of mankind. Astronomers belong, as a rule, to the first category, which, it must be admitted, is the more purely scientific. We not only find international co-operation in systematically mapping the universe of stars and keeping all portions of the universe under constant observation, but also when a particular object in the heavens presents itself under circumstances of peculiar interest or importance, the observatories of the world combine to ascertain the facts in a manner which is truly remarkable. As an illustration, I will instance the tiny planet Eros discovered a few years ago by De Witt. Recently the planet was in opposition and more favourably situated for observation than it will be again for thirty years. It was determined, at a conference held in Paris in July 1900, that combined work should be undertaken by no fewer than fifty observatories in all parts of the world. Beyond the fixing of the elements of the mean motion and of the perturbations of orbit due to the major planets, the principal object in view is the more accurate determination of solar parallax. To my mind this concert of the world, this cosmopolitan association of fine intellects, fine instruments, and the best known methods, is a deeply impressive spectacle and a grand example of an ideal scientific spirit. Other sciences are not so favourably circumstanced as is astronomy for work of a similar kind undertaken in a similar spirit. If in comparison they appear to be in a chaotic state, the reason in part must be sought for in conditions inherent to their study, which make combined work more difficult, and the results of such combined work as there is, less striking to spectators. Still, the illustration I have given is a useful object-lesson to all men of science, and may encourage those who have the ability and the opportunity to make strenuous efforts to further progress by bringing the work of many to a single focus.

In pure science we look for a free interchange of ideas, but in applied physics the case is different, owing to the fact that the commercial spirit largely enters into them. In a recent address, Professor Perry has stated that the standard of knowledge in electrical engineering in this country is not as high as it is elsewhere, and all men of science and many men in the street know him to be right. This is a serious state of affairs, to which the members of this Section cannot be in any sense indifferent. We cannot urge that it is a matter with which another Section of the Association is concerned to a larger degree. It is our duty to take an active, and not merely passive attitude towards this serious blot on the page of applied science in England. For this many reasons might be given, but it is sufficient to instance one, and to state that neglect of electrical engineering has a baneful effect upon research in pure science in this country. It hinders investigations in pure physics by veiling from observation new phenomena which arise naturally, and by putting out of our reach means of experimenting with new combinations on a large scale. Professor Perry has assigned several reasons for the present *impasse*, viz., a want of knowledge of mathematics on the part of the rising generation of engineers; the bad teaching of mathematics; the antiquated methods of education generally; and want of recognition of the fact that engineering is not on stereotyped lines, but, in its electrical aspect, is advancing at a prodigious rate; municipal procrastination, and so on. He confesses, moreover, that he does not

see his way out of the difficulty, and is evidently in a condition of gloomy apprehension.

It is, I think, undoubted that science has been neglected in this country, and that we are reaping as we have sowed. The importance of science teaching in secondary schools has been overlooked. Those concerned in our industries have not seen the advantage of treating their workshops and manufactories as laboratories of research. The Government has given too meagre an endowment to scientific institutions, and has failed to adequately encourage scientific men and to attract a satisfactory quota of the best intellects of the country to the study of science. Moreover, private benefactors have not been so numerous as in some other countries in respect of those departments of scientific work which are either non-utilitarian or not immediately and obviously so. We have been lacking alike in science organisation and in effective co-operation in work.

It has been attempted to overcome defects in training for scientific pursuits by the construction of royal roads to scientific knowledge. Engineering students have been urged to forego the study of Euclid, and, as a substitute, to practise drawing triangles and squares; it has been pointed out to them that mathematical study has but one object, viz., the practical carrying out of mathematical operations; that a collection of mathematical rules of thumb is what they should aim at; that a knowledge of the meaning of processes may be left out of account so long as a sufficient grasp of the application of the resulting rules is acquired. In particular, it has been stated that the study of the fundamental principles of the infinitesimal calculus may profitably be deferred indefinitely so long as the student is able to differentiate and integrate a few of the simplest functions that are met with in pure and applied physics. The advocates of these views are, to my mind, urging a process of 'cramming' for the work of life which compares unfavourably with that adopted by the so-called 'crammers' for examinations; the latter I believe to be, as a rule, much maligned individuals, who succeed by good organisation, hard work, and personal influence, where the majority of public and private schools fail; the examinations for which their students compete encourage them to teach their pupils to think, and not to rely principally upon remembering rules. The best objects of education, I believe, are the habits of thought and observation, the teaching of how to think, and the cultivation of the memory; and examiners of experience are able to a considerable extent to influence the teaching in these respects; they show the teachers the direction in which they should look for success. The result has been that the 'crammer' for examinations, if he ever existed, has disappeared. But what can be said for the principle of cramming for the work of one's life? Here an examination would be no check, for examiners imbued with the same notion would be a necessary part of the system; the awakening of the student would come. perhaps slowly, but none the less inevitably; he might exist for a while on his formulæ and his methods, but with the march of events, resulting in new ideas, new apparatus, new designs, new inventions, new materials requiring the utmost development of the powers of the mind, he will certainly find himself hopelessly at sea and in constant danger of discovering that he is not alone in thinking himself an impostor. And an impostor he will be if he does not by his own assiduity cancel the pernicious effects of the system upon which he has been educated. I do not, I repeat, believe in royal roads, though I appreciate the advantage of easy coaches in kindred sciences. In the science to which a man expects to devote his life, the progress of which he hopes to further, and in which he looks for his life's success, there is no royal road. The neglect of science is not to be remedied by any method so repugnant to the scientific spirit; we must take the greater, knowing that it includes the less, not the less, hoping that in some happy-go-lucky way the greater will follow.

At the beginning of the nineteenth century it was possible for most workers to be well acquainted with nearly all important theories in any division of science; the number of workers was not great, and the results of their labours were for the most part concentrated in treatises and in a few publications especially devoted to science; it was comparatively easy to follow what was being done. At the present time the state of affairs is different. The number of workers is very large;

the treatises and periodical scientific journals are very numerous; the ramifications of investigation are so complicated that it is scarcely possible to acquire a competent knowledge of the progress that is being made in more than a few of the subdivisions of any branch of science. Hence the so-called specialist has come into being.

Evident though it be that this is necessarily an age of specialists, it is curious to note that the word 'specialist' is often used as a term of opprobrium, or as a symbol of narrowmindedness. It has been stated that most specialists run after scientific truth in intellectual blinkers; that they wilfully restrain themselves from observing the work of others who may be even in the immediate neighbourhood; that even when the line of pursuit intersects obviously other lines, such intersection is passed by without remark; that no attention is paid to the existence or the construction of connecting lines; that the necessity for collaboration is overlooked; that the general advance of the body of scientific truth is treated as of no concern; that absolute independence of aim is the thing most to be desired. I propose to inquire into the possibility of such an individual existing as a scientific man.

I take as a provisional definition of a specialist in science one who devotes a very large proportion of his energies to original research in a particular subdivision of his subject. It will be sufficient to consider the subjects that come under the purview of Section A. though it will be obvious that a similar train of reasoning would have equal validity in connection with the subjects included in any of the other sections. I take the word 'specialist' to denote a man who makes original discoveries in some branch of science, and I deny that any other man has the right, in the modern meaning of the word, to be called by others, or to call himself, a specialist. I would not wish to be understood to imply a belief that a truly scientific man is necessarily a specialist; I do believe that a scientific man of high type is almost invariably an original discoverer in one or more special branches of science: but I can conceive that a man may study the mutual relations of different sciences and of different branches of the same science and may throw such an amount of light upon the underlying principles as to be in the highest degree scientific. I will now advance the proposition that, with this exception, all scientific workers are specialists; it is merely a question of degree. An extreme specialist is that man who makes discoveries in only one branch, perhaps a very narrow branch, of his subject. I shall consider that in defending him I am *à fortiori* defending the man who is a specialist, but not of this extreme character.

A subject of study may acquire the reputation of being narrow either because it has for some reason or other not attracted workers, and is in reality virgin soil only awaiting the arrival of a husbandman with the necessary skill; or because it is an extremely difficult subject which has resisted previous attempts to elucidate it. In the latter case, it is not likely that a scientific man will obstinately persist in trying to force an entrance through a bare blank wall. Either from weariness in striving, or from the exercise of his judgment, he will turn to some other subdivision which appears to give greater promise of success. When the subject is narrow merely because it has been overlooked, the specialist has a grand opportunity for widening and freeing it from the reproach of being narrow; when it is narrow from its inherent difficulty he has the opportunity of exerting his full strength to pierce the barriers which close the way to discoveries. In either case the specialist, before he can determine the particular subject which is to engage his thoughts, must have a fairly wide knowledge of the whole of his subject. If he does not possess this he will most likely make a bad choice of particular subjects, or, having made a wise selection, will lack an essential part of the mental equipment necessary for a successful investigation. Again, though the subject may be a narrow one, it by no means follows that the appropriate or possible methods of research are prescribed within narrow limits. I will instance the Theory of Numbers which, in comparatively recent times, was a subject of small extent and of restricted application to other branches of science. The problems that presented themselves naturally, or were brought into promi-

nence by the imaginations of great intellects, were fraught with difficulty. There seemed to be an absence, partial or complete, of the law and order that investigators had been accustomed to find in the wide realm of continuous quantity. The country as explored was found to be full of pitfalls for the unwary. Many a lesson concerning the danger of hasty generalisation had to be learnt and taken to heart. Many a false step had to be retraced. Many a road which a first reconnaissance had shown to be straight for a short distance, was found on further exploration, to suddenly change its direction and to break up into a number of paths which wandered in a fitful manner in country of increasing natural difficulty. There were few vanishing points in the perspective. Few, also, and insignificant were the peaks from which a general view could be gathered of any considerable portion of the country. The surveying instruments were inadequate to cope with the physical characters of the land. The province of the Theory of Numbers was forbidding. Many a man returned empty-handed and baffled from the pursuit, or else was drawn into the vortex of a kind of Maelström and had his heart crushed out of him. But early in the last century the dawn of a brighter day was breaking. A combination of great intellects—Legendre, Gauss, Eisenstein, Stephen Smith, &c.—succeeded in adapting some of the existing instruments of research in continuous quantity to effective use in discontinuous quantity. These adaptations are of so difficult and ingenious a nature that they are to-day, at the commencement of a new century, the wonder and, I may add, the delight of beholders. True it is that the beholders are few. To attain to the point of vantage is an arduous task demanding alike devotion and courage. I am reminded, to take a geographical analogy, of the Hamilton Falls, near Hamilton Inlet, in Labrador. I have been informed that to obtain a view of this wonderful natural feature demands so much time and intrepidity, and necessitates so many collateral arrangements, that a few years ago only nine white men had feasted their eyes on falls which are finer than those of Niagara. The labours of the mathematicians named have resulted in the formation of a large body of doctrine in the Theory of Numbers. Much that, to the superficial observer, appears to lie on the threshold of the subject is found to be deeply set in it and to be only capable of attack after problems at first sight much more complicated have been solved. The mirage that distorted the scenery and obscured the perspective has been to some extent dissipated; certain vanishing points have been ascertained; certain elevated spots giving extensive views have been either found or constructed. The point I wish to urge is, that these specialists in the Theory of Numbers were successful for the reason that they were not specialists at all in any narrow meaning of the word. Success was only possible because of the wide learning of the investigator; because of his accurate knowledge of the instruments that had been made effective in other branches; and because he had grasped the underlying principles which caused those instruments to be effective in particular cases. I am confident that many a worker who, from the supposed extremely special character of his researches has been the mark of sneer and of sarcasm, would be found to have devoted the larger portion of his time to the study of methods which had been available in other branches, perhaps remote from the one which was particularly attracting his attention. He would be found to have realised that analogy is often the finger-post that points the way to useful advance; that his mind had been trained, and his work assisted, by studying exhaustively the successes and failures of his fellow-workers. But it is not only existing methods that may be available in a special research.

Furthermore, a special study frequently creates new methods which may be subsequently found applicable to other branches. Of this the Theory of Numbers furnishes several beautiful illustrations. Generally, the method is more important than the immediate result. Though the result is the offspring of the method, the method is the offspring of the search after the result. The Law of Qaudratic Reciprocity, a corner-stone of the edifice, stands out not only for the influence it has exerted in many branches, but also for the number of new methods to which it has given birth, which are now a portion of the stock-in-trade of a mathematician.

Euler, Legendre, Gauss, Eisenstein, Jacobi, Kronecker, Poincaré, and Klein are great names that will be for ever associated with it. Who can forget the work of H. J. S. Smith on homogeneous forms and on the five-square theorem, work which gave rise to processes that have proved invaluable over a wide field, and which supplied many connecting links between departments which were previously in more or less complete isolation?

In this connection I will further mention two branches with which I have a more special acquaintance—the theory of invariants, and the combinatorial analysis. The theory of invariants was evolved by the combined efforts of Boole, Cayley, Sylvester, and Salmon, and has progressed during the last sixty years with the co-operation, amongst others, of Aronhold, Clebsch, Gordan, Brioschi, Lie, Klein, Poincaré, Forsyth, Hilbert, Elliott, and Young. It involves a principle which is of wide significance in all the subject-matters of inorganic science, of organic science, and of mental, moral and political philosophy. In any subject of inquiry there are certain entities, the mutual relations of which under various conditions it is desirable to ascertain. A certain combination of these entities may be found to have an unalterable value when the entities are submitted to certain processes or are made the subjects of certain operations. The theory of invariants in its widest scientific meaning determines these combinations, elucidates their properties, and expresses results when possible in terms of them. Many of the general principles of political science and economics can be expressed by means of invariantive relations connecting the factors which enter as entities into the special problems. The great principle of chemical science which asserts that when elementary or compound bodies combine with one another the total weight of the materials is unchanged, is another case in point. Again, in physics, a given mass of gas under the operation of varying pressure and temperature has the well-known invariant, pressure multiplied by volume and divided by absolute temperature. Examples might be multiplied. In mathematics the entities under examination may be arithmetic, algebraic, or geometric; the processes to which they are subjected may be any of those which are met with in mathematical work. It is the *principle* which is so valuable. It is the *idea* of invariance that pervades to-day all branches of mathematics. It is found that in investigations the invariantive fractions are those which persist in presenting themselves, even when the processes involved are not such as to ensure the invariance of those functions. Guided by analogy may we not anticipate similar phenomena in other fields of work?

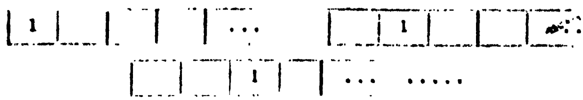
The combinatorial analysis may be described as occupying an extensive region between the algebras of discontinuous and continuous quantity. It is to a certain extent a science of enumeration, of measurement by means of integers, as opposed to measurement of quantities which vary by infinitesimal increments. It is also concerned with arrangements in which differences of quality and relative position in one, two, or three dimensions, are factors. Its chief problem is the formation of connecting roads between the sciences of discontinuous and continuous quantity. To enable, on the one hand, the treatment of quantities which vary *per saltum*, either in magnitude or position, by the methods of the science of continuously varying quantity and position, and, on the other hand to reduce problems of continuity to the resources available for the management of discontinuity. These two roads of research should be regarded as penetrating deeply into the domains which they connect.

In the early days of the revival of mathematical learning in Europe the subject of 'combinations' cannot be said to have rested upon a scientific basis. It was brought forward in the shape of a number of isolated questions of arrangement, which were solved by mere counting. Their solutions did not further the general progress, but were merely valuable in connection with the special problems. Life and form, however, were infused when it was recognised by De Moivre, Bernoulli, and others that it was possible to create a science of probability on the basis of enumeration and arrangement. Jacob Bernoulli, in his 'Ars Conjectandi,' 1713, established the fundamental principles of the Calculus of Probabilities. A

systematic advance in certain questions which depend upon the partitions of numbers was only possible when Euler showed that the identity $x^a x^b = x^{a+b}$ reduced arithmetical addition to algebraical multiplication and *vice versâ*. Starting with this notion, Euler developed a theory of generating functions on the expansion of which depended the formal solutions of many problems. The subsequent work of Cayley and Sylvester rested on the same idea, and gave rise to many improvements. The combinations under enumeration had all to do with what may be termed arrangements on a line subject to certain laws. The results were important algebraically as throwing light on the theory of Algebraic series, but another large class of problems remained untouched, and was considered as being both outside the scope and beyond the power of the method. I propose to give some account of these problems, and to add a short history of the way in which a method of solution has been reached. It will be gathered from remarks made above that I regard any department of scientific work, which seems to be narrow or isolated, as a proper subject for research. I do not believe in any branch of science, or subject of scientific work, being destitute of connection with other branches. If it appears to be so, it is especially marked out for investigation by the very unity of science. There is no necessarily pathless desert separating different regions. Now a department of pure mathematics which appeared to be somewhat in this forlorn condition a few years ago, was that which included problems of the nature of the magic square of the ancients. Conceive a rectangular lattice or generalised chess board (*cf.* 'Gitter,' Klein), whose compartments are situations for given numbers or quantities, so that there is a rectangular array of certain entities. The general problem is the enumeration of the arrays when both the rows and the columns of the lattice satisfy certain conditions. With the simplest of such problems certain progress had undoubtedly been made. The article on Magic Squares in the 'Encyclopædia Britannica,' and others on the same subject in various scientific publications, are examples of such progress, but the position of isolation was not sensibly ameliorated. Again the well-known 'problème des rencontres' is an instance in point. Here the problem is to place a number of different entities in an assigned order in a line and beneath them the same entities in a different order subject to the condition that the entities in the same vertical line are to be different. This easy question has been solved by generating functions, finite differences, and in many other ways. In fact when the number of rows is restricted to two, the difficulties inherent in the problem when more than two rows are in question do not present themselves. The problem of the Latin Square is concerned with a square of order n and n different quantities which have to be placed one in each of the n^2 compartments in such wise that each row and each column contains each of the quantities. The enumeration of such arrangements was studied by mathematicians from Euler to Cayley without any real progress being made. In reply to the remark 'Cui bono?' I should say that such arrangements have presented themselves for investigation in other branches of mathematics. Symbolical algebras, and in particular the theory of discontinuous groups of operations, have their laws defined by what Cayley has termed a multiplication table. Such multiplication tables are necessarily Latin Squares, though it is not conversely true that every Latin Square corresponds to a multiplication table. One of the most important questions awaiting solution in connection with the theory of finite discontinuous groups is the enumeration of the types of groups of given order, or of Latin Squares which satisfy additional conditions. It thus comes about that the subject of Latin Squares is important in mathematics, and some new method of dealing with them seems imperative.

A fundamental idea was that it might be possible to find some mathematical operation of which a particular Latin Square might be the diagrammatic representative. If, then, a one-to-one correspondence could be established between such mathematical operations and the Latin Squares, the enumeration might conceivably follow. Bearing this notion in mind, consider the differentiation of x^n with regard to x. Noticing that the result is nx^{n-1} (n an integer), let us inquire whether we can break up the operation of differentiation into n elementary portions, each of which will contribute a unit to the resulting coefficient n. If we

write down x^n as the product of n letters, viz., $xxxx$ . . ., it is obvious that if we substitute unity in place of a single x in all possible ways, and add together the results, we shall obtain nx^{n-1}. We have, therefore, n different elementary operations, each of which consists in substituting unity for x. We may denote these diagrammatically by



and from this point of view $\frac{d}{dx}$ is a combinatorial symbol, and denotes by the coefficient n the number of ways of selecting one out of n different things.

Similarly, the higher differentiations give rise to diagrams of two or more rows, the numbers of which are given by the coefficients which result from such differentiations. Following up this clue much progress has been made. For a particular problem success depends upon the design, on the one hand, of a function, on the other hand, of an operation such that diagrams make their appearance which have a one-to-one correspondence with the entities whose enumeration is sought. For a general investigation, however, it is more scientific to start by designing functions and operations, and then to ascertain the problems of which the solution is furnished. The difficulties connected with the Latin Square and with other more general questions have in this way been completely overcome.

The second new method in analysis that I desire to bring before the Section had its origin in the theory of partition. Diophantus was accustomed to consider algebraical questions in which the symbols of quantity were subject to certain conditions, such, for instance, that they must denote positive numbers or integer numbers. A usual condition with him was that the quantities must denote positive integers. All such problems and particularly those last specified are qualified by the adjective Diophantine. The partition of numbers is then on all fours with the Diophantine equation

$$\alpha+\beta+\gamma+\ldots+\nu=n,$$

a further condition being that one solution only is given by a group of numbers α, β, γ . . . satisfying the equation; that in fact permutations amongst the quantities α, β, γ . . . are not to be taken into account. This further condition is brought in analytically by adding the Diophantine inequalities

$$\alpha \geqq \beta \geqq \gamma \geqq \ldots \geqq \nu \geqq 0$$

ν in number. The importation of this idea leads to valuable results in the theory of the subject which suggested it. A generating function can be formed which involves in its construction the Diophantine equation and inequalities, and leads after treatment to a representative, as well as enumerative, solution of the problem. It enables further the establishment of a group of fundamental parts of the partitions from which all possible partitions of numbers can be formed by addition with repetition. In the case of simple unrestricted partition it gives directly the composition by rows of units which is in fact carried out by the Ferrers-Sylvester graphical representation, and led in the hands of the latter to important results connection with algebraical series which present themselves in elliptic functions and in other departments of mathematics. Other branches of analysis and geometry supply instances of the value of extreme specialisation.

What we require is not the disparagement of the specialist, but the stamping out of narrow-mindedness and of ignorance of the nature of the scientific spirit and of the life-work of those who devote their lives to scientific research. The specialist who wishes to accomplish work of the highest excellence must be learned in the resources of science and have constantly in mind its unity and its grandeur.

The following Papers were read:—

1. *On Elastic Fatigue, as shown by Metals and Woods.* *By* Professor A. Gray, *F.R.S.*, J. S. Dunlop, *and* A. Wood.

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2. *The Clearing of Turbid Solutions, and the Movement of Small Suspended Particles by the Influence of Light.* *By* Professor G. Quincke, *of Heidelberg.*—See Reports, p. 60.

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3. *On the Relation between Temperature and Internal Viscosities of Solids.* *By* Professor A. Gray, *F.R.S.*

4. *Note on Hydrostatic Pressure.* *By* W. Ramsay, *F.R.S.*, *and* G. Senter, *B.Sc.*

The problem of hydrostatic pressure has usually been treated as if the liquid, in which the floating solid is immersed, were a *continuum*. According to the molecular theory, however, all liquids must be regarded as consisting of discrete particles, moving among each other freely. Accepting this view, hydrostatic pressure must be attributed to the bombardment of the immersed body by molecules, or perhaps by congeries of molecules; and the kinetic energy of the molecules must be capable of transmission from those parts of the fluid which are not in contact with the solid to those which are in contact, in such a manner that the lower portions of the immersed solid are exposed to greater pressure than the upper, due to the kinetic energy of all portions of fluid at a higher level than the lower portions, and at a lower level than the upper portions.

Picton and Linder, working in the laboratory of University College, showed that colloidal solutions can be prepared of various degrees of fineness of the suspended particles; some solutions were prepared in which the particles were distinctly visible with high microscopic magnification, while others contained particles in such a minute state of subdivision that even under the highest power of a microscope, the colloidal solution appeared homogeneous, and the particles were too fine to polarise a beam of light by reflection. Between these two extremes intermediate grades were successfully made; while the particles of solid in such 'solutions' as contained visible solid were in rapid pedetic (Brownian) motion, a particular grade of 'solution' was prepared, in which, although the particles were too small to be visible, they revealed their presence by polarising light; and under the microscope an appearance of confused motion impressed itself on the eye; it seemed as though the particles were in such rapid motion that they did not stay in focus long enough to create a permanent visual impression.

The questions arose: do such particles produce hydrostatic pressure? is that pressure equal to the theoretical pressure which would be produced by a solution of the same density? at what stage of subdivision of the solid does such hydrostatic pressure become apparent?

An attempt has been made to answer the first two of these questions, and with fair success. The investigation will be continued in the hope of finding an answer to the third question.

The colloidal solution selected was one of arsenious sulphide in pure water. Such a solution is easily prepared by passing a current of sulphuretted hydrogen through an aqueous solution of arsenious acid to saturation, and then expelling excess of hydrogen sulphide by a current of hydrogen for several hours. The density of such a solution was determined in two ways: first by means of a Sprengel's pyknometer; and second by weighing in the solution a large cylinder of glass (65 c.c.), weighted with mercury, so as to make it sink. Corrections were introduced for reduction to weighing *in vacuo*, and for temperature.

Before commencing operations with the colloidal solution, experiments were made with a solution of barium chloride, so as to obtain a check on the results; the agreement is satisfactory.

	T	Hydrostatic method	T	Pyknometer	
I.	19·4°	1·02677	20°	1·02681	mean, 1·02683
	19·4°		20°	1·02685	
II.	20·67°	1·02928	20·47°	1·02931	
	20·67°		20·47°	1·02930	

The difference in the first case is 6 in 102,000; and in the second, 2 or 3 in 100,000.

With colloidal solution of arsenious sulphide, the data were:—

	T	Hydrostatic method	T	Pyknometer	Δ
I.	21·2°	1·01187	21·2°	1·01192	0·00005
	21·2°		21·2°	1·01193	
II.	20·7°	1·02323	20·7°	1·02330	0·00006
	20·7°		20·7°	1·02329	
III.	20·75°	1·02272	20·67°	1·02276	0·00005
	20·75°		20·67°	1·02277	
IV.	20·80°	1·01129	20·80°	1·01135	0·00005
	20·80°		20·80°	1·01134	

The solution IV. was prepared by diluting III.; the others were all specially prepared; they contained arsenious sulphide of such a degree of subdivision that the particles polarised light, but were invisible under a magnification of 1,000 diameters.

The influence of error in weighing is such that an error of 1 mgr. in the weight of the body in air or in solution would have caused an error of 2 units in the fifth decimal place: and 1° in reading temperature would have made an error of the same magnitude.

It will be noticed that the apparent density with the pyknometer always exceeds that with the float by 3 to 6 units in the fifth place of decimals; *i.e.*, by 3 to 6 parts in 100,000. It is probable that this is due to some unapplied correction; but it is not easy to allow for it. It may, we think, be taken as proved that colloidal arsenious sulphide of the state of subdivision used, exerts hydrostatic pressure as if it were a liquid; at any rate, it behaves as if it were in true solution like barium chloride.

It has long been the custom to determine the density of milk, which contains suspended fat globules, by means of a lactometer, which involves a hydrostatic method. The experiments cited show that this custom is justifiable.

5. *The Freezing Points of certain Dilute Solutions.* *By* E. H. Griffiths, *F.R.S.*

6. *The Buildings of the National Physical Laboratory.* *By* Dr. R. T. Glazebrook, *F.R.S.*

FRIDAY, SEPTEMBER 13.

The Section was divided into two Departments.

Department I.—Physics.

The following Report and Papers were read:—

1. *Report on Electrical Standards.*—See Reports, p. 31.

2. *Note on a Comparison of the Deposits in Silver Voltameters with different Solvents.* By S. Skinner, *M.A.*—See Reports, p. 32.

3. *The Discharge of Electricity through Mercury Vapour.* By Arthur Schuster, *F.R.S.*

The experimental investigation of the passage of electricity through mercury vapour is of interest on account of the metallic nature of the element, the monatomic characte: of the vapour, and the purity with which it can be obtained. Previous results of the author had led to the conclusion that the discharge of electricity through mercury vapour differed fundamentally from that taking place through other gases, but these results have been called in question by other experimenters.

The work now described has extended over two years, but did not lead to results which may be said to be decisive on the account of the extreme difficulty of excluding small traces of moisture. Though the mercury vapour experimented upon no doubt was much purer than that obtained by any previous observers, it was not absolutely free from some other gas, which, probably, was aqueous vapour. The width of the well-known dark space round the kathode observed was ten times larger than in air. This dark space, however, may possibly be due to the small remnant of impurity which, as has been pointed out, could not be excluded.

4. *Sur les Effets magnétique de la Convection électrique.* Par Dr. V. Crémieu.

5. *Photoelectric Cells.* By Professor G. M. Minchin, *M.A.*, *F.R.S.*

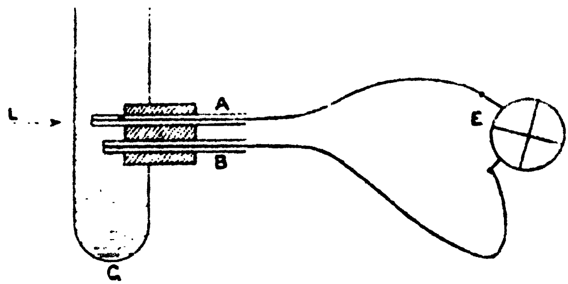
During the past summer I have been engaged on the study of the photoelectric cells with which I had measured the voltage produced by the light of the stars. The object of this investigation was to discover whether the life of a cell could be in any way prolonged or not, and also to find the best liquid that could be employed.

In these cells the surface, which is sensitive to light, is a thin layer of selenium spread on the end of an aluminium wire, the selenium layer being heated gradually after it has been spread as a black viscous liquid on the end of the wire until it assumes the brownish grey colour which characterises the state in which it is sensitive to light. The aluminium wire is contained in a glass tube, which the wire should so completely fit as to prevent the ascent of a liquid into the tube—a condition which it is impossible to fulfil, as the aluminium wire cannot be sealed into a glass tube. It is essential for complete success that only the selenium layer on the end of the wire should come into contact with the liquid. Let us imagine two such selenium-coated aluminium wires immersed in a small glass tube containing a liquid, one of the wires being completely screened from light, while the selenium on the end of the other can be exposed to light. In the dark there should be no voltage exhibited by this cell when its two wires are connected with an electrometer. If the wire to be exposed is left completely naked—*i.e.*, in free contact with the surrounding liquid—no voltage (or almost none) will be developed when its selenium end is exposed to light. This result is undoubtedly due to short-circuiting in the cell itself when the light acts; but if

this wire is surrounded by a tightly fitting glass tube a very great voltage is produced by light.

The accompanying figure represents the two aluminium wires, A and B, contained in a cork which fits tightly into a glass cell, C, containing a liquid; the wires are each contained in a tightly fitting glass tube and are connected with the poles of a quadrant electrometer, E. The ends of the wires are exactly flush with the ends of the glass tubes, which dip into the liquid, and these ends are coated with the selenium layers. We shall suppose that the wire B is screened from the incident light L. Each aluminium wire is about $\frac{3}{4}$ mm. or $\frac{1}{2}$ mm. thick, nothing depending on the diameter of the wire—*i.e.*, on the area of the sensitive selenium surface—provided that the *whole* of this surface is illuminated by the incident light.

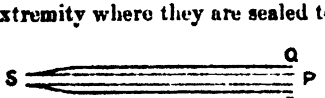
Now the question will naturally occur, Why do we use aluminium and not some other metal, *e.g.*, platinum, as the base for the selenium? The answer is that many other metals have been tried, and none of them gives results approaching those given by aluminium. Platinum develops only about half the voltage which, under the same circumstances, will be given by aluminium. Metals with which selenium combines readily are useless: copper, silver, and tin are very poor. Now as regards the liquids which are most effective, I have found the following to be extremely good: œnanthol, acetone, succinate of ethyl, malonic ether, methyl-



hexylketone, ethyl and methyl benzoate, methyl carbonate, lactic acid, lactate of ethyl, and lactate of methyl.

Cyanide of ethyl is somewhat effective; but such liquids as anisol, mustard oil, ethyl acetate, valerate of ethyl, and valerate of methyl are not sensitive at all.

Within the last few weeks, however, I discovered a fact which will certainly modify some of my statements about the want of sensitiveness of liquids—the fact, namely, that nearly all of the little glass tubes which surrounded the aluminium wires, and on which I had relied for insulating these wires from the liquid, were very good conductors! I found that if the electrometer was charged by a Daniell cell, which was then withdrawn, so that the poles of the electrometer were insulated, one of my glass tubes laid across from one pole to the other rapidly discharged the electrometer; and drying the glass tube did not much improve its insulation. As a result of this, I have recently used a compound glass tube—one tube inside another with a layer of air between them, except at a common extremity where they are sealed together, thus:



The inner tube is P, sealed to the outer, QQ, at the end S, where the selenium surface of the wire contained in the inner tube comes into contact with the liquid.

Except in the neighbourhood of S, this interposes a layer of air between the tube P and the liquid, and the result is a great improvement.

A more effective way still is to coat the aluminium wire with an insulating varnish; but this varnish must be such as not to be dissolved by the liquid which we employ.

I am now engaged on this part of the problem, and it is mainly this which has compelled me to delay the star measurements which I was to have resumed at Sir

Robert Ball's observatory at Cambridge in continuation of the results which the late Professor FitzGerald, Mr. W. E. Wilson, and I obtained in Mr. Wilson's observatory in Westmeath.

It is desirable that I should give a notion of the magnitudes of the voltages developed in these cells by lights of various intensities.

(1) An ordinary paraffin candle, held at a distance of 2 feet from a cell in which the liquid was malonic ether, was found to give slightly more than ·25 of a volt.

(2) For small intensities of the incident light the voltage will be proportional to the square root of the intensity; that is to say, the voltage varies inversely as the distance of the luminous source from the cell.

(3) A paraffin candle, at a distance of 8 feet from the cell, gives a voltage almost exactly equal to that given by the light of Vega when this is concentrated by a reflecting telescope whose aperture is 2 feet.

(4) For strong lights the law that the square of the voltage developed in the cell is proportional to the intensity of the incident light does not hold, as is shown by the following observation recently made:—

Room darkened and cell in the dark, except that the light of the paraffin lamp of the electrometer was, to some extent, reflected from the walls of the room: this very feeble light gave a deflection of 11 divisions on the scale. One candle held at 2 feet from the cell gave (not allowing for the above 11 divisions) 76 divisions. Two candles held close together at 2 feet from cell gave (not allowing for the 11 divisions) 99 divisions. (One volt was represented by 275 divisions.)

Let i be the energy incident on the sensitive plate when nothing but the reflected lamplight falls on it; let I be the incident energy due to one candle at 2 feet, and I′ that due to two candles at 2 feet; then we have

$$i = k \times 11^2$$
$$\mathrm{I} + i = k \times 76^2$$
$$\mathrm{I}' + i = k \times 99^2$$

These give

$$\therefore \frac{\mathrm{I}'}{\mathrm{I}} = \frac{99^2 - 11^2}{76^2 - 11^2} = 1{\cdot}71$$

but I′ should be 2I, so that the law cannot hold. Indeed, diffused daylight itself develops only about ·5 volt in the cell.

These cells are sensitive to all parts of the spectrum, the voltage developed by the yellow being slightly greater than that due to the other parts.

As to the nature of the action of light in a selenium cell, I may quote the following interesting experiment which was made by Mr. Shelford Bidwell, and communicated to me in a letter recently.

Mr. Bidwell took a piece of platinum foil and coated it by electrolysis with a very thin layer of selenium by making it the cathode in a solution of selenious oxide, or of Se dissolved in HNO_3. The platinum foil, thus covered with red Se, was gradually heated on a brass plate and thus brought into the well-known condition in which it is sensitive to light.

When this coated strip was immersed in a beaker of tap water in presence of a clean platinum strip, there was little (if any) voltage in the dark; but when diffused daylight was allowed to fall on the coated strip a voltage of ·101 was developed. (This was very much less than the voltage which would have been developed in the cells which I have just described; but the reasons for this are obvious.)

In this cell, as in all other forms of selenium cells, the selenium plate was to the inactive plate as copper to zinc, and from this Mr. Bidwell concludes that, just as Zn tends to combine with oxygen in H_2O, so Se in the light tends to combine with hydrogen and form H_2Se.

In order to test this, Mr. Bidwell took two small test tubes, and into each he put some acetone and a strip of platinum coated with selenium; each tube was closed by a vaselined cork, and from each cork was suspended in the tube a clean

strip of silver. One of these tubes was put into a box in a dark room, and the other was exposed to light in a conservatory. Here they were left for five years—forgotten, I presume—and when examined at the end of that time it was found that the silver strip in the tube exposed in the conservatory was very much blackened, while that in the tube kept in the dark was scarcely discoloured at all.

6. *On the Necessity for Postulating an Ether.* B. HOPKINSON.

The difference between those who say that there must be a medium to transmit gravitation and those who deny its necessity is a purely metaphysical one. All the facts of gravitation can be described or expressed without any reference to a medium. In like manner it would appear so far as terrestrial phenomena go that the facts of light transmission can be so described, in which case the necessity of an ether for conveying light is again purely metaphysical. We may say that a luminous body A causes a disturbance at P in its neighbourhood; the disturbance is properly represented by a vector at right angles to the line joining A to P, and its amount is $\frac{F(r-Vt)}{r^2}$, where t is the time, r the distance AP, and V a velocity. Aberration is expressed by saying that if A be in motion relative to P, in a direction at right angles to AP, the disturbance experienced at P is the same as that which would be produced by a similar luminous body at A′ at rest relative to P, where $\frac{AA'}{AP} = \frac{\text{velocity of A}}{V}$ and AA′ is in the direction of motion of A. There is here no mention at all of a medium, but a complete account is given of the cardinal optical phenomena.

This mode of expressing the facts, however, fails to cover the phenomena of spectroscopic double stars. The periodic doubling of lines in their spectra shows these stars (apparently single as seen in a telescope) to consist of two components moving one about the other with an orbital velocity which can be computed from the displacement of the lines. When the two components are in the line joining the star to the earth, there is no doubling of the lines, but one component is moving to the right and the other to the left with this orbital velocity. Now according to the above-stated expression for aberration, or any expression which only involves the motion of source and receiver relative to each other, the two components should, when in the line of sight, be apparently separated owing to the difference of their motions relative to the earth. The angular amount of the separation of the two components would be equal to $\frac{\text{twice orbital velocity}}{\text{velocity of light}}$ an amount sufficient in some cases to be visible to the naked eye. The star would in fact appear periodically to be double, the doubling occurring alternately with the displacement of the lines in the spectroscope. Since no such doubling takes place we infer either that aberration cannot be completely expressed in terms of relative motion of source and receiver, or that the accepted theory of these stars is wrong. The former alternative, which seems the more probable, forces one to recognise a something other than matter to which the motion of matter can be referred. In fact, it may almost be said that in this way the ether is made manifest to our senses as having position. This reason for postulating an ether differs in kind from the metaphysical reasons usually advanced; it may be described as furnishing a logical necessity for an ether.

7. *On the Change of Conductivity of Metallic Particles under Cyclic Electro-motive Variation. By* Professor JAGADIS CHUNDER BOSE, *M.A., D.Sc.*

(1) Under the action of electric radiation the conductivity of metallic particles exhibits variation. In the positive class, like iron, there is an increase,

and in the negative, like K, &c., a diminution of conductivity. Each class again falls into two sub-classes—(*a*) sensitive substances which undergo self-recovery, and (*b*) sensitive substances which do not. In the case of self-recovering substances the conductivity distortion varies with the intensity of radiation. Under the continued action of radiation the distortion attains a maximum, balanced by force of restitution, and on the cessation of radiation there is an elastic self-recovery.

(2) The three classes of substances, positive, negative, and neutral, may be distinguished by their peculiar characteristic curves.

(3) The change produced in the sensitive substance by the action of radiation is not, normally speaking, chemical.

(4) The conductivity change is produced, not only by very rapid, but also by comparatively slow electric variation. Generally speaking, all the conductivity variation effects produced by electric radiation can be reproduced by comparatively slow cyclic electro-motive variation.

(5) Electric conduction in metallic particles sensitive to electric radiation does not obey Ohm's l w. The conductivity is not constant and independent of the electro-motive force, but varies with it. In the positive class the characteristic curve—in which the ordinates represent the currents, and the abscissæ the electro-motive force—is concave to the axis of the current. The conductivity increases *continuously* with increasing electro-motive force. The variation of conductivity in the lower portion of the curve is small, but increases with great rapidity in the upper portion.

(6) The curve obtained with strong is steeper than that with feeble initial current.

(7) There is found, especially when the initial current is feeble, a critical electro-motive force, at which the conductivity change becomes so rapid as to produce an almost abrupt bend in the curve. Stronger initial current appears, not only to lower the critical point, but also to mitigate the abruptness of this change.

(8) The effect of electro-motive force in modifying the conductivity of the conducting layer is well seen in self-recovering substances. There is a definite conductivity corresponding to a definite electro-motive force. As the electro-motive force is increased, the sensitive molecular layer is strained, and a definite increase of conductivity produced. When the increased stress is removed the corresponding strain also disappears, and there is an elastic recovery of its former molecular and conductive state. Hence when it is carried through a complete cycle of electro-motive variation, with moderate speed, the forward and return curves coincide, and the substance remains, at the end of the cycle, in its original molecular condition.

(9) This is the case where there is complete recovery on the removal of the stress. With non-recovering substances we find an outstanding residual effect. In a curve taken with cyclic electro-motive variation the forward and return curves do not coincide, but enclose an area. There is a hysteresis. The larger the range of the electro-motive variation, the greater is the area enclosed. There is a residual conductivity variation at the end of the cycle which may be dissipated by vibration.

FRIDAY, SEPTEMBER 13.

DEPARTMENT II.—ASTRONOMY.

CHAIRMAN: Professor H. H. TURNER, *D.Sc., F.R.S.*

The Chairman delivered the following Address:—

IT was hoped, as you are doubtless all aware, that this Chair would be taken by the Astronomer Royal for Scotland, Dr. Copeland; but unfortunately illness has prevented him coming to the Meeting. In doing what I can to fill his place

at very short notice, I shall not attempt, nor would you expect, a formal address such as we hoped to hear from him; but I will venture to put before you one or two reflections on a topic which has been much before my attention during the last few years because directly connected with my own work, and which has a special interest for us from the allusions made to it yesterday morning by the President of our Section, viz., the question of scientific co-operation. It is a matter of considerable importance to astronomers, who have to deal with numerous observations and calculations; indeed, the millions and billions which express the distances, sizes, or ages of the heavenly bodies, and which are used to such good purpose by some lecturers for startling the imaginations of their audiences, scarcely surpass the numbers which must be used to express the work to be done by an astronomer. The enterprise on which we are engaged at the Oxford University Observatory at the present moment is the measurement of a quarter of a million star-places, which will take us about seven years; and we are only one of eighteen observatories co-operating in a scheme of work. The product of eighteen by a quarter of a million does not bring us near the billions; but if we are minded to produce big numbers we might remember that in the determination of each individual star-place a good many figures are required. At Oxford we try to keep the number to the irreducible minimum, but it certainly exceeds thirty even there; while at other observatories it reaches 300 or 400. Thus we can with ease secure a creditable position in the thousands of millions in respect of this one piece of work, and the lapse of a century or two is all that is necessary to produce billions of figures in the ordinary course of astronomical observation. It is clear that in such work co-operation is an all-important factor, and the study of the best means for securing it and for using it when secured may well claim a share of our attention.

I may pause for a moment to consider the possibility that our experience may be of value to the devotees of other sciences. 'Other sciences,' said Major MacMahon yesterday, 'are not so favourably circumstanced as is Astronomy for work of a similar kind undertaken in a similar spirit.' But what may be true to-day may not be true to-morrow. It was not astronomers, but mathematicians, who first showed the value of a certain kind of co-operation. Major MacMahon reminded us that the Spitalfields weavers founded a mathematical society in 1717, and thus anticipated by more than a century the formation of the Astronomical Society in 1821, which ultimately absorbed its prototype. Possibly in the future mathematicians will find the need of co-operation of this other kind, which consists in sharing a great piece of work among several workers for the sake of comfort and rapidity, and so may profit by our example, as we formerly profited by that of the Spitalfields weavers. And there are indications that in another science, that of Zoology, the time may be close at hand when co-operation between workers, of a type very similar to that in full swing in Astronomy, will be a boon, if not a necessity. Professor Karl Pearson, Professor Weldon, and others are introducing into zoology numerical operations on a large scale, which promise further and further increase; and they would no doubt be ready to indicate even now enterprises of a valuable kind which they are only deterred from undertaking by their magnitude, and which a suitable scheme of co-operation might bring within the range of practical politics. Hence we should look to our methods of work in Astronomy with the responsibility attaching to those who are leading where others may follow; and above all things take care to make clear any mistakes we have made, so that others may perhaps profit by our experience.

If it seems invidious thus to emphasise our mistakes, I would remind you that astronomical co-operation has not always been successful; indeed, it has very often ended in failure. I do not mean simply failure to attain its object. The band of astronomers who divided the sky between them at the end of the eighteenth century to look for a minor planet met with this kind of failure, for the first discovery fell by the irony of Fate to another, who was not engaged in any special search of the kind. This unlucky accident must not, however, make us forget that the co-operators worked diligently side by side for several years. Failure of a more real kind has overtaken enterprises to chart the stars or to map the Moon,

which have proceeded very little further than the preliminary organisation. Some workers have dropped out early in the history of the scheme, some have not even started, and the blanks have not been filled up; sooner or later—generally sooner—the scheme has been abandoned. The curious may read of some of these schemes in back numbers of the 'Monthly Notices,' though some of them never got into print, and are only to be traced in the Minutes of the Royal Astronomical Society. And yet of many of them, if not all, it may safely be said that a little more energy on the part of *somebody* would have produced an assured success; somebody to see that the gaps were filled up, and dilatory workers hastened or superseded; somebody to be a sort of foreman of the works. It does not seem unlikely that this general supervision is best performed by one not actually engaged in the work himself—a man of affairs. One of our great London schoolmasters declares that a nominally idle man should be at the head of all enterprises; that he never knew any good come of any work where there was not 'a man with his hands in his pockets looking after it.' We have scarcely found this to be a necessity in Astronomy; for the men who have looked after the eighteen observatories, taking part in the Astrographic Chart, have been Directors of the Paris Observatory—men with many things to claim their attention. To the individual energy of the late Admiral Mouchez and his successors the work owes a great deal. It fell to their lot to overcome the difficulties I have indicated; to undertake the voluminous correspondence necessary at the start; and to fill up gaps in the ranks of workers. Last July it was found that of the eighteen observatories which had promised to take part, three had made no start; and M. Lœwy forthwith superseded them and found three others. Thus the risk of incompleteness has been removed; and we may hope that one danger which threatens such schemes has been successfully averted.

But the removal of this danger draws our attention immediately to another—that of taking far too long in finishing the work. The project for making the Chart was originally discussed fourteen years ago, in 1887; and it was urged by many of those then present that a reasonable time, say ten years, should be fixed for the completion of the whole. In spite of the representations of this prudent minority, the programme was made an ambitious instead of a modest one, and some stretching has been done since, with the result that after fourteen years only one or two observatories are within sight of the goal, the majority seeing from ten to twenty years' work ahead of them; and, as above remarked, there are three which have not yet started. With this experience we may well ask whether the limit proposed even by the prudent minority was not too high; and whether it would not be well to fix five years as a limit to any scheme of co-operation which is as yet on paper only.

The danger of attempting too much is illustrated in a somewhat different way by the Eros campaign. It will be clear from what has been already said that the eighteen observatories responsible for the Chart have their hands quite full; and now comes a special occasion—an opportunity that will not occur again for thirty years—to determine the Solar parallax. Last winter the newly-discovered planet Eros was known to be coming close to us, and we had an occasion of more value than the Transits of Venus. What were the eighteen observatories to do? They could not at any rate refuse to take photographs, and this has been done; even this meant a great deal of additional work for some people for a few months; but it is a mere trifle compared with the work that is still to come in measuring and reducing the plates, which will be a sensible fraction of the work already projected for the Chart. Which is to be done first? Prudence suggests finishing one enterprise before beginning another, putting aside the Eros plates until the Chart work is finished. On the other hand there are thirty other observatories sharing the Eros work with the original eighteen, and they will be more or less impatient for our results. In this dilemma some rather unsatisfactory compromise will no doubt be adopted, but we may heave another sigh that the advice of the prudent minority in 1887 was not taken, for in that case not one or two but many of the eighteen observatories might have completed the Chart work before Eros came.

I now pass to a different kind of danger to which co-operation renders us

liable. To secure homogeneity in the work it is necessary to bind the associating individuals by certain rules, and we run some risk of checking that originality which is almost vital in scientific work. There is scarcely any scientific operation so mechanical that it may be safely left in entire charge of those without originality and the liberty to use it. Quite recently a scheme of co-operation has been adopted in the preparation of the nautical almanacs of the different nations. It is thought that certain calculations to be performed are so well settled that independent calculation is a needless waste of labour, and thus certain sections of, say, the American Nautical Almanac and our own will be henceforth identically the same, printed from the same manuscript computations. I cannot but regard the project with some alarm. The risks against which we are guarded by independent computation may be small, but I cannot believe them to be evanescent, and I attach some value to the healthy stimulus of comparison (or we may perhaps say competition) even for nautical almanacs. Differences revealed by such comparisons in the past have often been traced to causes which were by no means obvious or unworthy of attention.

But without laying too much stress on this case, which is obviously an extreme one, we can, I think, well understand how the taking part in a co-operative scheme may lower the tone of scientific work. There is a very real possibility of replacing the alert spirit of investigation by a mere mechanical regularity; nay, even of making one who should be an astronomer into a mere drudge. This has at times been the declared method of great astronomers with their subordinates; they have professed themselves quite able to do all the thinking required, and looked for the help, not of intelligent assistants, but of mere drudges. This was Pond's view, and more or less that of Airy in his early years at Greenwich; and I need not stop to point out the errors into which it led them, and from which we are still struggling to free ourselves. There are, I am happy to think, few who would now deliberately advocate it, and we need not waste words in trying to convince these. But if we acknowledge the crushing out of intelligent independence in subordinates to be a mistake, how much greater is the evil if it spreads through the whole staff of an observatory, including the Director himself? And this is at least a *possible* result of co-operation. We can only too easily imagine a scheme of work in which the rules are laid down so completely and so stringently by the central body that nothing is left to the initiative or originality of the individual observatories; and the Director of such a one might find himself with nothing to do but see that the rules were adhered to. If the work were at the same time planned to extend over a period of ten or twenty years, as is quite possible in Astronomy, we can well understand that his efficiency as an intelligent scientific worker might become seriously affected. We must not shut our eyes to this danger. Astronomical work is terribly liable to settle down into routine as we all know; and the existence of so many small observatories where nothing is done beyond routine observations with the transit circle is not a credit to us. It is reassuring to find that many of them are ready to use opportunities which present themselves. For instance, when the Eros work was planned, fifty observatories responded to the call for volunteers. But is there not even here another point of view? What were all these observatories doing before, that they are able so readily to take up a new project? Some of them we know had enough on hand already, and only added the Eros work with reluctance; but it is to be feared that others hailed it as a welcome opportunity to do something of some use, not having been able to think of anything for themselves. This thinking of what one's work is to be is, of course, the hardest part of research—devising something to do that shall be a real step in advance. Some fortunate men find it comparatively simple, but to the majority it is a labour and toil, and only through much tribulation do they enter their kingdom—their own domain in which they recognise their own true work. It is much easier for such to turn aside and follow some king who has come to his crown more easily; to take a share in a great piece of work organised by some master-mind. But is not this a serious loss to them and to science? May not schemes of co-operation kill the originality of the humbler workers by removing the incentive to independent thought?

Here, however, I end, for the present at any rate, my list of the risks and dangers which co-operation brings in its train. It is time to turn to the other and brighter side of the matter; for there is a brighter side, which presents itself, as it should to experimental philosophers, when we come to practical working as opposed to forecasting; and it is because the great scheme of the Astrographic Chart illustrates vividly both the dark side and the bright, both the possible evils of such schemes and the actual benefits which may replace them under certain circumstances, that I have ventured to select it so often for reference in these remarks. We have seen how it has escaped the premature decease which has befallen other such schemes, owing in great measure to the energy of the central authority. The mistake of attempting too much is unfortunately now irremediable in this particular case; but it may serve as a warning on future occasions. It remains to show how the danger of crippling individuality has been averted in an unexpected, almost a comical, manner.

At the outset this danger was distinctly threatening. At the earlier conferences there was manifest anxiety, chiefly on the part of those who were not going to do the work, to bind down the workers rather stringently by rules of procedure. The anxiety seemed to be intensified rather than diminished by the circumstance that it was not very clear what these rules ought to be. Where several courses were open, each found its champion, and the discussion was perhaps most animated in the cases where the teaching of actual experience was least available. On several occasions a decision was only arrived at by an expedient which seems to be familiar in Continental meetings, but is little known in England; perhaps it deserves a wider recognition. When formal discussion waxes warm, the President declares the meeting dissolved, for ten minutes of informal conversation. The meeting forthwith breaks up into animated knots of eager talkers; opponents who have been addressing one another with the meeting between them rush across the room to each other and put their points with renewed emphasis and unfettered gesture, and for ten minutes there is apparent confusion and some noise. But when the President's bell again rings, the effect of the outburst is manifested in a restoration of sobriety and the passing of a resolution; and so the number of resolutions mounts up, and by the end of the Conference a respectable list of them is ready for the printer; a list quite long enough to quench any spark of originality in the individuals taking part in the work. But now comes the unforeseen feature of the enterprise. The participating workers go off to their observatories with a copy of these rules in their pockets, and do not observe them. Such as they find convenient they adhere to closely; but when they find by experience that a rule will not work, they do not hesitate to prefer their experience, as good and faithful experimental philosophers should. And their individual experiences were by no means similar, so that the sheet of rules was torn across in all sorts of directions; the original copy would be now barely recognisable by those who subscribed to it.

But then is anything left? Is not this the practical failure of the scheme? On the contrary it was its salvation. The diversity of experience was not fundamental, but to a great extent apparent only. The rules which were broken were those which experience proved non-essential, and which ought never to have been made; and when those who had actually carried out a considerable portion of the work met last year, they found that they had arrived at practically the same conclusions by a diversity of routes. It was inevitable that they should, rules or no rules, if they went to work honestly and perseveringly; and if some went a longer way and some a shorter to the same goal this was, after all, an unimportant matter beside the fact that they all arrived at last. Had they not thrown off the needless constraints they might never have arrived at all.

The reality of this happy consummation was illustrated by two minor incidents, which I will mention. At this last Conference several points were brought up for discussion which had not been previously considered. Guided by experience, no attempt was made in general to frame new rules of procedure: the object was tacitly assumed to be that the different workers should compare notes for their own guidance. But there were some present, especially among those not

participating in the work, who had not profited by the lessons of the past; and one of them read out a rather elaborate resolution for deciding one of the points in question on a uniform plan. It was just such a resolution as would have led to an excited debate at the earlier Conferences and ultimately to a cut-and-dried rule. It was now received in embarrassed silence. Then one who had gauged the opinion of the meeting more adequately rose to point out how retrogressive it was. With the utmost courtesy to his colleague and in the most genial manner he pointed out that such a resolution was both dangerous and useless, and was better let alone, which was accordingly done.

Again, one of the co-operating directors rose to ask for guidance on a doubtful point. There were certain plates which might or might not be considered properly falling to his share, according to the definition of his boundary. In this case individual opinion was deliberately subordinated to the decision of the meeting. Would the meeting please decide the point? Surely here the meeting might give a decision without danger. But the meeting had been humbled, and was no longer in the mood to give decisions. Proposals to direct the questioner to take the doubtful plates, to recommend him to do it, and to encourage him to do it, were successively considered and rejected as being too dictatorial; and it was finally decided that the meeting would not forbid him to take the extra plates if he so wished!

But the comedy of this result has a very serious significance. We may heartily congratulate ourselves that the time is not yet come when astronomers are prepared to lose their individuality in a co-operative scheme of work; and still more that such schemes can be found where such loss of individuality is unnecessary. May it not be said that something very similar has been realised in the case of the other scheme of co-operation referred to by the President of the Association yesterday, the scheme for a Catalogue of Scientific Literature? The original proposals were of a kind which left too little scope for the individuality of the different sciences. Fortunately the mistake was rectified promptly, and the present plan leaves much more to individual judgment. Some such compromise would seem to be essential (if we are not generalising too hastily) to the success of co-operative enterprises in science. We must, above all things, take care not to crush individuality. I would even go so far as to say that so much of the element of *competition* as can be preserved without endangering uniformity in essentials should be diligently cultivated. Add that the original scheme should be as modest as possible, and that an energetic man should be put in a position to wake up the dilatory and to ensure that the pace, which is necessarily that of the slowest, be not funereal, and I venture to think that we may eliminate failure from co-operative scientific enterprises.

The following Papers were read:

1. *On the Possibility of Systematic Error in Photographs of a Moving Object.* By A. R. Hinks, *M.A.*

An *à priori* objection to the method of obtaining the position of a planet from photographs is the alleged possibility of systematic error due to the fact that the images either of the stars or the planet must be short trails, and the ends of these trails may not be symmetrical with respect to the mean epoch of exposure. In photographing Eros at Cambridge last winter for the determination of the solar parallax the exposures were made following alternately the stars and the planet. A comparison of the two series will not show the existence of a systematic error constant for stars of all magnitudes, but it would show an error which was a function of the magnitude. Forty exposures each of eighteen selected stars have been measured, and show no trace of such an error. The author concludes, from the absence of a differential effect between stars of different magnitudes, that the absolute systematic error due to trail is probably insensible.

2. *The Essentials of a Machine for the Accurate Measurement of Celestial Photographs.* *By* A. R. Hinks, *M.A.*

It is now within the power of amateur astronomers to do work of the highest value by measuring photographs made by the existing telescopes of the public observatories in such numbers that they cannot all be measured and discussed at the observatories themselves. When this is more fully realised there will be some demand for a suitable measuring machine at a not extravagant price. The author attempts to define the essentials of the simplest machine which will do work of the highest accuracy.

The machine shall measure one coordinate at a time on plates impressed with a standard 5 mm. réseau.

To ensure that the error in the measure due to the machine and the observer shall not be a large part of the whole error, the machine must read to 0·0001 of a réseau interval R.

The object glass of the microscope should project the image of a R-square with magnification unity on to a divided glass scale in the eyepiece, to divide it into one hundred parts. This scale should have the spaces numbered, not the divisions. R-lines and star discs are then referred to the centre of the scale space nearest each by a micrometer screw, which may be applied (1) to the plate carriage, (2) to the scale, (3) to the objective. The last has not been done, but it promises the advantage over the others that it brings the micrometer head at a convenient distance from the eye; and since the range of motion required is small (0·5 mm. is ample) the objective could be carried in the centre of an arm pivoted at one end and pressed against the screw at the other, which would be simple to make.

The objective must give a flat field over at least 5 mm. The tube carrying the eyepiece and scale must have a focussing movement, preferably independent of the objective, which should have a small independent range of adjustment to make the R-square fit the scale and reduce errors of run. This does not disturb the focus if the objective is midway between plate and scale.

The plate carriage must move on two rectangular slides, which need not be really true. It may be moved by hand, but a quick rack and pinion motion is much better. Clamps are not necessary if the carriage is counterpoised. Rough setting scales with adjustable pointers are necessary. The plate should be brought up by springs under three studs, and an orientating screw at one corner is required.

Uniform illumination is given by a simple convex lens below the plate and a concave mirror. It is most important that the observer should be shielded from direct light by black curtains and screens, that he may be able to keep both eyes open.

The essentials are: (1) objective giving a flat field, and (2) divided scale in the eyepiece, good optical work; (3) micrometer screw motion to subdivide the scale spaces, the only part which wants really good mechanical work; (4) simple focussing movement; and (5) orientating screw for the plate.

Semi-essentials, which quickly pay for themselves in time saved and fatigue avoided, are:—

(6) The adjustment of objective independent of microscope tube by a divided head; (7) rack and pinion motion for the plate carriage; (8) lens and concave mirror illumination; (9) light screens.

For a discussion of most of these points reference is made to a paper by the author, 'Monthly Notices of the Royal Astronomical Society,' 1901 May.

3. *Note on the Singkep Commutator.* *By* David P. Todd.

At last year's meeting of the Association I described the Tripoli commutator, a mechanical device which I employed at that station on May 28, 1900, for operating the eclipse instruments automatically. The fortunate accident of locating the instruments on the roof or terrace of the British Consulate made it

possible to drive the cords from the commutator barrel by gravity. The method could not be conveniently used except under like circumstances of elevation.

To operate the instruments at Singkep, Netherlands Indies, was a very different problem, and led to the devising of two improvements in this type of mechanical commutator which make it universally adaptable to the needs of both astronomers and physicists:—

(*a*) Instead of a single barrel or drum I used as many drums as there were instruments to be operated. Each drum was provided with a collar and set-screw, so that the process of adjusting one instrument and its automatic movements did not disturb the adjustments of others already made.

(*b*) Instead of gravity as a power to turn the drums, they were turned by hand, timed accurately to the motion of a pendulum; and the commutator cords, after unwinding from the several drums and doing their work in tripping the escapements, were returned over pulleys, each to its individual drum, where they wound up on one side just as fast as they unreeled from the other. This simple arrangement easily gave accommodation for the 80 feet of cord required by the 6m. 20s. duration of totality.

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4. *The Drift in Longitude of Groups of Faculæ on the Sun's Surface.* *By the* Rev. A. L. Cortie, *S.J.*, *F.R.A.S.*

From a discussion of the Potsdam photographs for the year 1884, Wilsing concluded that faculæ did not show the drift in longitude with decrease in latitude exhibited by sun-spots. An opposite conclusion was derived from plates covering the period 1891–94 at Pulkowa, by Statonoff. On these plates no facula was followed for more than three days, and the measures were made on selected points in the faculous groups. From the study of selected groups of faculæ in the year 1889, Father Sidgreaves showed that groups considered as a whole during long periods of time drifted with the spots. The present paper is supplementary to that of Father Sidgreaves, and while traversing the same ground, gives a more detailed discussion of the observations. Moreover, it is illustrated by diagrams which show the drift in a very convincing way. The periods of time during which the faculæ were followed ranged from 19 to 120 days. The year 1889 was selected as being a minimum year of solar activity, and therefore presenting less difficulty for the identification and following of the several groups of faculæ than in a maximum year. Moreover, to make identification certain, of 121 groups drawn and measured during that year, all but thirteen were excluded. These latter groups were all connected with sun-spots, and passed through the various phases of growth which characterise such groups. In the study of the drift, Carrington's method, set forth in his 'Observations of Solar Spots,' was exactly followed. A centre of each group was chosen which appeared to give the most trustworthy result for diurnal motion. But every member of each group had previously been put down in its true heliographic position on a set of charts, one to each solar rotation. The positions were determined from the original drawings by means of a series of accurate heliographic projections. The Table gives the results from the measurements.

Latitude	Number of Groups	Mean Daily Angular Motion: Faculæ Groups (Stonyhurst)	Mean Daily Angular Motion: Spot Groups (Carrington)
		°	°
	1	14·5	14·3
	1	14·3	14·7
− 2	1	14·5	13·9
− 3	1	14·4	14·2
− 8	4	14·8	14·3
− 9	3	14·4	14·4
−24	1	14·0	13·8
−26	1	13·9	13·7

The Table shows that, at least in the cases discussed, there is a real drift in ongitude with reduction of latitude. This is especially noticeable in the cases between -26° and -8°. The diagrams in which the faculæ are set down in position at successive periods show the drift in a most striking and convincing manner. An apparent lagging of faculæ behind the leading spot of a group is accounted for by the disappearance of the following members of the spot groups, and not by a retrograde drift of the faculæ.

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5. *On an Exceptional Case in the determination of the Constants of a Photographic Plate from known Stars. By Professor* H. H. Turner, *F.R.S.*

At the University Observatory, Oxford, the places of stars on about 800 photographic plates, each $2^\circ \times 2^\circ$, have already been measured; the whole number of plates to be measured as the share of this observatory in the International Astrographic Survey being 1,180. Each plate contains on an average about 350 stars, but the number varies considerably (from 100 to 2,000). Of these a certain number (from 10 to 30 per cent.) have already been observed on the meridian, so that their places are known; and from these known places the 'plate constants' are determined (scale value, orientation, &c.), so that the places of the remaining stars in the sky can be inferred from the measures of the plate. The constants are found by two sets of linear equations, one set from measures of the x coordinates, another from y: and the correctness of the solution is checked (a) by the agreement of the results from the two sets, which are solved independently; (b) by the accordance of the residuals for the known stars with those found from other plates.

The equations are solved, not by the method of least squares, but by a process in many ways equivalent to it. To avoid the heavy work of squaring and multiplying numerous coefficients, the stars are grouped so that by mere addition we can form three equations presenting the chief features of the normal equations which arise in the work by least squares, viz., that the coefficient of each unknown quantity should be relatively large in one equation. In almost all cases hitherto this process, which is comparatively simple and expeditious has been found quite satisfactory.

A plate with centre $13^h\ 0^m$, $+27^\circ$, taken on 1890 May 5, presents a curious exception. There are only fifteen 'known' stars on it, and these are so arranged (all near the line $x=y$) that the usual method of grouping failed to give a solution at all. A deliberate regrouping was then made with special attention to the characteristics of the plate, but the solution obtained was unsatisfactory when judged by either of the criterions (a) and (b) above mentioned.

The machinery of 'least squares' was then set in motion, with the result that a satisfactory solution was obtained. It seems worthy of note that this machinery does practically give satisfactory results in cases where simpler methods fail. This instance is of some importance as representing an extreme case out of 800 tried.

6. *On the Position of a Planet beyond Neptune. By* G. Forbes, *F.R.S.*

SATURDAY, SEPTEMBER 14.

The Section was divided into two Departments.

Department I.—Mathematics.

A joint Discussion with Section L on the Teaching of Mathematics, opened by Professor John Perry, *F.R.S.*

DEPARTMENT II.—PHYSICS.

The following Report and Papers were read:—

1. *Report on Radiation in a Magnetic Field.*—See Reports, p. 39.

2. *Note on a Method of determining Specific Heats of Metals at Low Temperatures. By* T. G. BEDFORD, *M.A., and* C. F. GREEN, *M.A.*

The specific heats of solids at temperatures below 0° C. have hitherto generally been determined by an obvious slight modification of the method of mixtures as generally used for temperatures between 0° and 100° C.

It was suggested to us by Mr. E. H. Griffiths that better results might be obtained by adopting a method which can be regarded as analogous with one which has already been used with success for the 0° C. to 100° C. range, viz., that of Joly's steam calorimeter. The metal, whose specific heat is required, having been previously weighed in water kept at 0° C., is cooled to a low temperature and then again immersed in the ice-cold water. The metal, with the coating of ice thus formed on it, is again weighed in the water. From the difference in the two weights the mass of ice formed is calculated, the density of ice being known, and thence the specific heat of the metal is obtained in terms of the latent heat of ice.

The experiments have been merely of a preliminary character, but they have served to suggest the following as an appropriate form of apparatus.

The metal to be investigated should be enclosed in a cylindrical box, and experiments performed first with the box empty and then when it contains the metal. Then if the walls of the box be of sufficient thickness, this differential method would eliminate to a great extent corrections for the suspension wire, for the gain of heat by the metal and the deposition of hoar-frost upon it during its transit through the air, &c. The essential feature of such a box is that its volume should not be altered by opening and closing it.

The 'cooler' used by us consisted of three coaxial cylinders. The metal experimented upon was suspended in the inner of the three chambers thus formed, the middle chamber contained the cooling agent and the outer chamber formed an air-jacket.

It appeared that the best method of determining the temperature of the box would be to bring it into direct metallic connexion with the thick walls of the inner part of the cooler and to insert a platinum resistance thermometer in the walls.

In the method briefly sketched above, the accurate determination of the rise in temperature of the water in a calorimeter in experiments by the method of mixtures is replaced by two weighings. These weighings must, however, be performed with great accuracy, since the difference in the observed weights caused by the formation of ice is only $\frac{1}{11}$th of the weight of ice formed.

The chief difficulties of the method are:—

(1) Uncertainty as to the density of the ice owing to the presence of air in the water.

(2) The fact that the water cannot be stirred during the process of weighing, and that therefore its temperature begins to rise above 0° C. and the ice gradually melts.

3. *A New Gauge for Small Pressures. By* Professor EDWARD W. MORLEY *and* CHARLES F. BRUSH.

The paper describes two forms of gauge for the measurement of small pressures of a gas. It was especially devised in order to measure the pressure of aqueous vapour. For this purpose McLeod's gauge cannot easily be employed, owing

chiefly to the fact that the amount of absorption by the walls of the gauge changes slowly when the volume of the vapour is changed by the compression utilised in that instrument.

In both forms of our gauges, a mercurial siphon gauge, having tubes of five centimetres diameter, is mounted on an instrument like a level-trier, and differences of level in the two sides are measured by determining the inclination of the whole gauge which is required to bring the two surfaces to coincide with two fiducial points in the axes of the two arms of the gauge. From the measured inclination, together with the known linear distance of the two fiducial points, is computed the difference of level of the two surfaces of mercury.

This principle (due to M.) has been carried out in two ways. In the first, the siphon gauge is carried on a kind of bridge, supported at one end by two points which rest on a horizontal plate on a solid pier; and, at the other, by the point of a micrometer screw, which itself rests on the same horizontal plate. In the axes of the two limbs of this gauge are two platinum points, at the same level. The amount of mercury in the gauge can be changed by a fine adjustment.

When the pressures in the two arms of the gauge are the same, we determine the zero reading. The amount of mercury in the gauge is altered till one fiducial point barely touches the mercury, while the other creates a depression. Then the inclination of the bridge is changed till the two depressions become equal. Mercury is now removed from the gauge, when one depression will commonly disappear before the other. The adjustment is repeated till both depressions disappear together, or till both are apparently equal when made as small as can be seen. The reading of the micrometer screw now is the zero reading, and marks when the two points are in the same horizontal plane.

If now the pressures in the two parts of the gauge become unequal, their difference can be measured by determining what new inclination must be given to the bridge and gauge in order to bring the two fiducial points into coincidence with the mercury surfaces again. Knowing the linear distance between the fiducial points, we can compute their difference of level in their new position, and so measure the difference of pressure between the two sides of the gauge.

No optical appliances are needed in the use of this form of gauge. The observer, moving his eye up and down, causes the image of a window bar to move across the depression in the mercury made by the fiducial points. From the appearance of this image, he can, even without the aid of a magnifying glass, equalise the depressions with a mean error less than the five-thousandth part of a millimetre; after some practice, of course. But an observation requires two, three, or four minutes.

We have therefore constructed two gauges of a second form, employing the same general principle, but also utilising an optical appliance (due to B.) by which a reading is made as speedily as is an ordinary micrometric reading, while the accuracy attained is even increased. Between the two arms of the siphon gauge with its wide tubes is placed a pair of mirrors, so adjusted that the two fiducial points, as well as the two images of these in the mercury, are seen side by side in the field of a microscope carried on the apparatus and moving with the tubes and mirrors. The surface of the mercury is not seen; the two pairs of images of the points, one belonging to the right arm of the gauge, and one to the left, are partially superposed, so that the extreme ends of the points are perhaps a tenth of a millimetre apart. If now the two real points are equidistant from the surfaces of the mercury, the two pairs of images will seem equidistant; if not, the inclination of the whole system of gauge, mirrors, and microscope is changed till the distance between the left-hand pair seems equal to that between the right-hand pair. This is as easy as the bisection of a point with the wire of a micrometer.

Mendeléef found it necessary to grind and polish the external and internal surfaces of the glass tubes of his gauges, in order to eliminate errors due to irregular refraction through irregular surfaces. In our apparatus the points of the tube through which the fiducial points are viewed are always rigorously the same. We therefore need only to secure an area in each tube through which we can get sufficiently good definition; it is easy to select such an area in the tube which is about

to be worked at the lamp, and then to secure that the selected area shall occupy the desired position in the completed apparatus.

To secure precision many precautions were taken. The construction and mounting of the instrument is much like that of an astronomical instrument. A massive cast-iron standard, designed so as not to be distorted by changes of temperature, rests on an isolated stone pier; on it, moving on trunnions in V-shaped supports like those of a transit instrument, is carried the plate on which siphon gauge, mirrors, and microscope are fixed. The free surface of the mercury in each arm of the gauge is five centimetres in diameter. The tube connecting them is two centimetres in diameter, and is but two centimetres below the free surface; so that the temperature of the two columns of mercury shall be equalised rapidly. Good illumination is provided, with care to minimise the access of heat to the mercury. The pair of mirrors is provided with every motion required to bring the two fiducial points into focus at once, and to give the images of the points any desirable position in the field of the microscope. The ends of the points are wrought into small hemispheres. With all these precautions, as well as many others, we have been able to make measurements in which the mean error of a single reading is not very much greater than a ten-thousandth of a millimetre.

4. *The Transmission of Heat through Water Vapour.* *By* Charles F. Brush *and* Professor Edward W. Morley.

In the discussion which was elicited by the paper of Mr. Brush on a new gas whose power of transmitting heat is vastly greater than that of hydrogen, Sir William Crookes suggested that the observed phenomena might perhaps be due to water vapour, and described experiments which seemed to 'show that, at high vacua, water-gas is a better conductor of heat than either air or hydrogen at similar pressures.'

Being able now to measure small pressures directly, we have determined the rate of transmission of heat through water vapour at pressures from that of saturation at 0° to less than a millionth of an atmosphere. The three gauges described before have been used in three series of experiments with three different apparatus.

At low pressures, water vapour transmits heat more rapidly than air, but not so rapidly as hydrogen. The superiority over air is a maximum at twenty or thirty millionths of an atmosphere, and is not far from 30 per cent. At sixty or eighty millionths, air and water vapour transmit heat at the same rate; at higher pressures, water vapour transmits heat less rapidly than air at the same pressures. Statements more precise than these cannot now be made, because the form and dimensions of the apparatus used modify slightly the curves which represent the relations between pressure and rate of transmitting heat, and the place of intersection of the curves is therefore uncertain.

5. *Comparison of the Constant Volume and Constant Pressure Scales for Hydrogen between* 0° *C. and* −190° *C. By* Morris W. Travers, *D.Sc.*, *and* George Senter, *B.Sc.*

The authors describe a modified form of constant volume gas thermometer in which the average temperature of the stem—the part connecting the bulb with the so-called 'dead space'—is determined from the readings of a secondary gas thermometer the bulb of which lies side by side with the stem of the main thermometer. The relation between the two scales was deduced from the expansion of hydrogen at constant pressure between −190° C. and 0° C. The arrangements used to determine this expansion were as follows:—The bulb of the constant volume thermometer was immersed in liquid air side by side with another bulb, which we may call the constant pressure bulb, filled with hydrogen at a known pressure, the temperature being deduced from the readings of the constant volume thermometer. The gas in the constant pressure bulb was then

pumped off and measured in a constant volume burette at a known temperature near that of the atmosphere, the relative volumes of bulb and burette being such that the pressure on the gas in the constant volume burette was as nearly as possible that under which the gas was confined in the constant pressure bulb at the lower temperature. By the above arrangement errors due to uncertainty in the temperature of connections, &c., are eliminated.

The results are as follows:—

Temperatures from constant volume thermometer		Pressure on gas in bulb of constant pressure apparatus in millimetres	Volume of bulb of constant pressure apparatus in c.c.	Volume coefficient of H between −190° C. and 0° C.
H scale	Cent. scale			
83·50	−189·54	642·85	16·140	·0036690
83·15	−189·89	683·70	12·990	·0036710
83°·00	−190·04	719·70	12·990	·0036714
83·07	−189·97	790·85	16·140	·0036730
86·85	−186·19	794·55	13·908	·0036730

These results indicate that the volume coefficient varies with the pressure on the gas at the lower temperature, and if these values are plotted it will be seen that the value of the coefficient approaches ·003660 when the pressure becomes small. This result is in agreement with theory. The value of the coefficient at normal pressure is ·003667, and if we apply this result to the calculation of corresponding temperatures on the two scales we find:—

Temperature on constant volume scale . . . . −190° C.
Temperature on constant pressure scale . . . . −190°·5 C.

6. *Note on the Variation of the Specific Heat of Water. By* Professor H. L. Callendar, *F.R.S.*—See Reports, p. 34.

7. *The Laws of Electrolysis of Alkali Salt Vapours. By* Harold A. Wilson, *D.Sc., M.Sc., B.A., Clerk-Maxwell Student, Cambridge University.*

The method employed in the experiments described in this paper was the following:—A current of air, containing a small amount of salt solution in suspension in the form of spray, was passed between two concentric cylinders of platinum heated in a gas furnace. These cylinders were maintained at a large difference of potential by means of a storage battery, and the current between them through the stream of air and salt vapour was measured at various temperatures and with different E.M.F.'s.

It was found that above 1300° C. and with more than 800 volts P.D. the current through the salt vapour became 'saturated,' that is, it was not increased appreciably either by raising the temperature or increasing the E.M.F. applied.

This saturation current was measured for a number of different alkali metal salts. The table on the next page contains the results obtained.

It will be seen from the above results that the product EC is approximately a constant for solutions of the same concentration. Also EC is ten times greater with solutions of 10 grams in a litre than with solutions of 1 gram in a litre.

It follows therefore that the saturation current through an alkali salt vapour is (1) proportional to the amount of any one salt passing between the electrodes, and (2) inversely proportional to the electrochemical equivalent of the salt sprayed.

These results are exactly analogous to Faraday's Laws of Electrolysis for

Liquid Electrolytes, and consequently they establish the analogy between conduction of electricity by salt solutions and that by salt vapours.

Salt in the Solution sprayed	Conc. of Solution (Grms. per litre)	Electro-chemical Equivalent of Salt (E)	Saturation Current observed (C)	EC
CsCl	10	168	15·1 $\times 10^{-4}$	2·54 $\times 10^{-1}$
RbI	10	212	13·5 ,,	2·86 ,,
KI	10	166	16·4 ,,	2·72 ,,
NaI	10	150	16·4 ,,	2·46 ,,
CsCl	1	168	1·61 ,,	2·70 $\times 10^{-2}$
Cs_2CO_3	1	163	1·61 ,,	2·62 ,,
RbI	1	212	1·25 ,,	2·65 ,,
RbCl	1	121	2·24 ,,	2·71 ,,
Rb_2CO_3	1	115	2·44 ,,	2·80 ,,
KI	1	166	1·66 ,,	2·75 ,,
KBr	1	119	2·13 ,,	2·53 ,,
KF	1	58	4·42 ,,	2·57 ,,
K_2CO_3	1	69	4·00 ,,	2·76 ,,
NaI	1	150	1·82 ,,	2·73 ,,
NaBr	1	103	2·44 ,,	2·52 ,,
NaCl	1	59	4·73 ,,	2·79 ,,
Na_2CO_3	1	53	4·73 ,,	2·51 ,,
LiI	1	134	2·03 ,,	2·72 ,,
LiBr	1	87	3·12 ,,	2·72 ,,
LiCl	1	43	6·25 ,,	2·69 ,,
Li_2CO_3	1	37	7·48 ,,	2·77 ,,
			Mean .	2·67

8. *Preliminary Note on the Theory of the Lippmann Electrometer and related Phenomena.* By F. G. Cottrell.

In the paper it is pointed out that in the determinations of single potential differences between metals and solutions of their salts by means of either the capillary electrometer or dropping electrodes the assumption has up to the present been made that the presence of a large amount of 'indifferent' and good conducting electrolyte in uniform concentration throughout effectually prevents the differences of concentration of the metallic ions within the solution from producing any measurable electromotive forces. This is shown to be the case only—

(1) When the total quantity of depolarising agent (usually a mercury salt) in the dilute portion of the solution (layer next the mercury in the capillary) is large in comparison to that used up at the electrode during the measurements; or (2) when the depolarising agent can diffuse from the concentrated to the dilute portion in a practically undissociated state.

In none of the forms of capillary electrometer or dropping electrode as yet employed for quantitative measurement is the first of these alternatives satisfied for such electrolytes as dilute sulphuric or hydrochloric acids or potassium chloride. It is, however, for those (such as certain strengths of alkaline sulphide or cyanide solutions) in which the unpolarised mercury is already at its maximum surface tension. The second alternative is also not satisfied by solutions of the strong mineral acids or their salts, but probably is by cyanides, and to some

extent by iodides. Whether the sulphides also belong here is harder to say, but is not unlikely.

It has long been admitted as one of the most vulnerable points in the theories of dissociation and the capillary electric phenomena that the values computed for such cells as Hg | KCl | Na_2S | Hg by the use of these methods for the terminal E.M.F.'s and Planck's equations for the liquid contact (KCl | Na_2S) do not agree with the values obtained by direct measurement of the cell as a whole. The tendency seems to have been to regard the contact Na_2S | Hg as the disturbing element; but the views here presented point to the discrepancy really lying in the determination of the value for Hg | KCl. This, of course, has a direct and important bearing on the value for the standard electrodes now in common use.

The same considerations serve to clear up some of the discrepancies between theory and experiment in the phenomena of galvanic polarisation in general.

The present paper is merely intended to indicate the line of reasoning which has led up to, and act as a preliminary notice for, a series of experiments aimed at a clearer separation and measurement of the individual components of these phenomena which the author has at present in hand, and expects soon to bring forward as basis for a more thorough and conclusive treatment of the whole subject.

9. *Effect of Non-Electrolytes on the Lippmann Electrometer Curve.* *By* J. A. CRAW.

10. *Determination of the Surface Tension of Mercury by the Method of Ripples.* *By* J. A. CRAW.

11. *The Potential Differences of Allotropic Silver.* *By* J. A. CRAW.

MONDAY, SEPTEMBER 16.

The Section was divided into two Departments.

DEPARTMENT I.—MATHEMATICS.

The following Report and Papers were read:—

1. *Report on Tables of certain Mathematical Functions.*

See Reports, p. 54.

2. *A Criterion for the Recognition of the Irregular Points of Analytic Functions.* *By* Professor MITTAG-LEFFLER, *Foreign Member R.S.*

Let $c_0 + c_1(x-a) + c_2(x-a)^2 + \ldots$ be a lower series, and let us make the analytical continuation of this series along the line L, which starts from a. The paper dealt with the problem of finding a criterion which will determine the first singular point x upon L, which is found on proceeding from a towards infinity.

The condition found was as follows:—

Denote by ϵ and δ two positive quantities less than unity, and by

$$\kappa_1^{(n)}, \kappa_2^{(n)}, \ldots \quad \kappa_{n-1}^{(n)} \quad \ldots$$

constants defined by the formula

$$\lambda(\lambda+1)\ldots(\lambda+n-1)=\lambda^{(n)}+\kappa_1^{(n)}\lambda^{n-1}+\ldots\kappa_{n-1}^{(n)}\lambda$$

Then the necessary and sufficient condition that x be the first singular point on L, as we go from a to infinity is that the inequality

$$\left|1!\,\kappa_{n-1}^{(n)}c_1\left(\frac{x-a}{\log\frac{1}{\alpha}}\right)+2!\,\kappa_{n-2}^{(n)}c_2\left(\frac{x-a}{\log\frac{1}{\alpha}}\right)^2+\ldots\;n!\,c_n\left(\frac{x-a}{\log\frac{1}{\alpha}}\right)^n\right|>n!\left(\frac{1-\epsilon}{1-\alpha}\right)^n$$

holds independently of α, however small ϵ may be, for an infinite number of values of n; while the inequality

$$\left|1!\,\kappa_{n-1}^{(n)}c_1\left(\frac{(x-a)(1-\delta)}{\log\frac{1}{\alpha}}\right)+2!\,\kappa_{n-2}^{(n)}c_2\left(\frac{(x-a)(1-\delta)}{\log\frac{1}{\alpha}}\right)^2+\ldots\right.$$

$$\left.n!\,c_n\left(\frac{(x-a)(1-\delta)}{\log\frac{1}{\alpha}}\right)^n\right|<n!\left(\frac{1-\epsilon}{1-\alpha}\right)^n$$

holds for all sufficiently large values of n where we take α first and then ϵ sufficiently small.

3. *Poincaré's Pear-shaped Figure of Equilibrium of Rotating Liquid.* *By* G. H. DARWIN, *F.R.S.*

Ellipsoidal harmonic analysis has usually been presented in such a form as to make numerical calculation almost impossible, but the author believes that he has succeeded in removing this defect in a paper for the 'Philosophical Transactions,' now in the press. By aid of the methods of that paper the limit of stability of Jacobi's ellipsoid becomes calculable. According to the principles established by M. Poincaré, stability ceases when we arrive at a stage where a coefficient of stability vanishes, and where there is interchange of stabilities between two coalescent series of figures. The figure which coalesces with the Jacobian at this point is the pear-shaped figure sketched by Poincaré. No attempt is made in this paper to indicate the methods pursued, but results will merely be given.[1]

If ω denotes the angular velocity of an ellipsoid of liquid, and ρ the density, it is well known that bifurcation of the Maclaurin ellipsoid occurs when $\frac{\omega^2}{2\pi\rho}=\cdot1871$, and when a number μ to which the moment of momentum is proportional is $\cdot30375$.[2]

One of the equatorial axes then begins to elongate, and the other to shorten, as the angular velocity diminishes and the moment of momentum increases. These ellipsoidal figures with three unequal axes are the Jacobian ellipsoids.

The problem to be solved is to find when a coefficient of stability in the Jacobian series first vanishes, and to determine the nature of the figure which coalesces with the Jacobian.

If the phraseology of spherical harmonic analysis be adopted, it is found convenient to take as the principal axis of quasi-symmetry for the ellipsoidal harmonics the longest axis of the Jacobian ellipsoid. Then it appears that the first to vanish of the coefficients of stability is that corresponding to the third zonal harmonic.

The following short table gives the leading facts concerning the Jacobian ellipsoids as far as just beyond their instability. The last line in the table gives the corresponding facts as to the critical Jacobian, which is a figure of bifurcation. The axes of the ellipsoids a, b, c are given in such a form that their product abc is

[1] A paper giving the details of the investigation was presented to the Royal Society in October 1901.

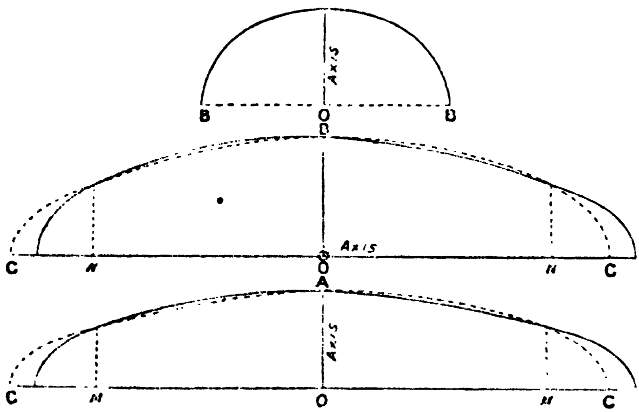
[2] See *Proc. R.S.*, vol. xli. p. 319.

equal to unity. The function μ was referred to above, and exhibits the increase of moment of momentum, whilst the angular velocity falls.

[illegible]	b	c	$\frac{\omega}{2\pi\rho}$	μ
6977	1·1972	1·1972	·1871	·30375
696	1·123	1·279	·186	·306
6916	1·0454	1·3831	·1812	·3134
6765	·9235	1·6007	·1659	·3407
6494	·8111	1·899	·1409	·3920
·65066	·81498	1·88583	·14200	·38957

In the figure the dotted line shows the three principal sections of the critical Jacobian and the full line shows the pear-shaped figure, the amount of departure from the ellipsoid being, of course, drawn on an arbitrary scale.

The reader who compares the figure of the critical Jacobian defined in the last line of the table and shown in the figure with Poincaré's sketch will perceive that it is considerably longer than he had supposed. The resemblance of the new figure to a pear is also much less remarkable than in the conjectural sketch.



$$OA = \cdot 65066,\ OB = \cdot 81498,\ OC = 1\cdot 88583;\ \frac{\omega^2}{2\pi\rho} = \cdot 14200$$

$$\frac{OM}{OC} = \cdot 75806,\ \frac{ON}{OC} = \cdot 78899$$

4. *The Simple Pendulum without Approximation.* *By* Professor A. G. Greenhill, *F.R.S.*

5. *Spherical Trigonometry.* *By* Professor A. G. Greenhill, *F.R.S.*, *and* C. Vernon Boys, *F.R.S.*

6. *On the Partition of Series each Term of which is a Product of Quantics.* *By* Major P. A. MacMahon, *F.R.S.*

7. *On Idoneal Numbers.*

By Lt.-Col. ALLAN CUNNINGHAM, *R.E.*, *and the* Rev. J. CULLEN, *S.J.*

About the year 1778 Euler discovered the existence of a class of positive numbers (mn), such that if an *odd* number N be expressible in *only one way* in the form $(mx^2 + ny^2)$ [with mx prime to ny] or $(x^2 + mny^2)$ [with x prime to mny], then N is either a *prime* or the *square of a prime*. These numbers he styled *numeri idonei* from their special fitness to aid in the detection of high primes. He gave rules for their discovery, and actually discovered sixty-five of them, the largest being 1848, and stated that there are no more $> 1{,}848$ but $< 10{,}000$. The joint authors have recently extended their search up to 101,220 by a sort of graphic process of solving simultaneous linear congruences (invented by the Rev. J. Cullen), with the result that no more such numbers exist $> 1{,}848$, but $< 101{,}220$. (The whole of the work ending in this result has been done *independently* by each of the joint authors.)

As to the forms $(mx^2 \sim ny^2)$, $(x^2 \sim mny^2)$ mere automorphs of the same form, *i.e.*, products of the form by its unit-form $\tau^2 - mnv^2 = 1$, are *not to be considered as distinct* forms. With this proviso it is found that negative idoneals $(-mn)$ are very numerous. Gauss's tables show that, excluding squares, all but thirty-five of the numbers < 328 yield negative idoneals. Also the authors find that all the known *positive* idoneals (except 37) are also *negative* idoneals.

Several new theorems on quadratic forms whose determinant is an idoneal were announced.

As an application all the odd numbers of form $(x^2 + 1848y^2)$, wherein x is prime to $1848y$, from 10,000,000 to 10,100,000, have been examined; the 189 numbers shown below were found to be expressible in *only one way* in that form, and (squares having been excluded) are therefore all *Primes*.

[This work was done by two computers *independently* under Colonel Cunningham's supervision.]

10,00	10,01	10,02	10,03	10,04	10,05	10,06	10,07	10,08	10,09
0,873	0,113	0,817	0,057	0,809	0,049	0,009	0,377	1,633	0,369
1,209	0,401	2,497	0,777	0,881	0,217	0,537	0,449	1,681	0,441
1,401	1,457	3,049	1,113	1,529	0,769	0,801	1,097	1,801	0,609
4,017	1,961	3,073	1,233	1,817	1,141	1,041	1,433	2,713	1,953
5,241	4,097	3,553	2,793	2,321	1,801	1,269	1,601	2,857	2,457
5,361	4,481	4,249	3,321	2,993	2,953	1,353	1,889	3,049	3,561
5,601	4,673	4,393	3,753	3,713	3,289	1,473	2,129	3,217	4,137
6,417	4,937	5,233	4,161	6,689	3,481	1,881	2,297	4,369	4,473
8,553	5,009	5,569	4,809	7,073	3,649	2,193	2,393	4,537	5,409
8,769	5,657	6,097	4,929	7,577	3,913	2,361	2,561	4,561	5,457
9,609	6,329	6,193	5,169	8,273	3,961	2,889	2,969	4,897	5,649
9,729	6,521	6,241	5,601	9,449	5,329	4,569	3,281	5,161	6,417
	6,953	7,081	7,449	9,593	5,497	5,553	3,449	5,329	6,969
	7,529	7,249	8,337	9,713	6,337	5,841	3,737	6,217	7,497
	7,841	8,011	8,697	9,953	6,601	5,889	4,241	6,913	8,169
	8,033	8,209	9,177		6,841	6,081	4,409	7,009	8,201
	8,297	8,881	9,297		7,513	6,681	5,129	7,177	8,313
	8,633		9,969		7,777	6,753	5,297	8,017	8,433
	8,969				9,193	8,193	5,657	8,761	9,153
	9,689					9,537	5,921	9,073	9,321
							7,433		9,681
							7,937		
							8,489		
							8,513		
							8,993		
							9,353		
							9,833		

8. *Determination of Successive High Primes.* (*Second Paper.*) *By* Lt.-Col. ALLAN CUNNINGHAM, *R.E.*, *and* H. J. WOODALL, *A.R.C.Sc.*

A general method was previously explained of determining, in a compendious manner, the *whole* of the primes within a given range. Tables have now been prepared showing the *lowest* factors (>5) of *all* the numbers between ($2^{25} \mp 1020$), *i.e.*, between 33,553,412 and 33,555,452, thus bringing them *all* within the power of the existing large factor-tables. Hereby are detected the *whole* of the High Primes (128 in number) within that range, and also the *whole* of the Secondary High Primes (45 in number) contained as factors of the numbers within that range. [The *whole* of the work required has been done by each of the joint authors independently.]

There is a long sequence of 73 composite numbers between 33,554,393 and 33,554,467, and one of 51 composites between 11,184,889 and 11,184,941.

List of 128 *High Primes between* ($2^{25} \mp 1020$).

33,553, . . .				33,554, . . .					33,555, . . .			
—	511	651	771	009	201	383	593	839	019	167	287	421
—	517	657	787	011	221	393	639	849	037	191	289	439
—	519	661	799	021	239	467	641	867	061	199	293	449
—	537	679	837	051	249	473	693	891	073	209	317	—
—	547	693	879	077	267	501	699	903	077	217	341	—
—	549	697	901	083	273	503	737	929	079	241	373	—
—	577	727	909	093	291	509	743	951	089	251	377	—
417	607	739	967	123	317	519	761	959	101	259	383	—
451	613	747	969	137	341	527	771	971	131	271	391	—
463	633	759	991	159	347	579	789	977	149	281	397	—
489	649	769	999	167	371	581	831	993	163	283	419	—

List of 45 *High Primes between* $\frac{1}{3}(2^{25} \mp 1080)$.

11,184, . . .									11,185, . . .		
—	497	553	611	671	737	799	869	941	001	037	147
451	527	557	617	683	743	829	871	959	007	049	157
469	529	577	659	703	757	839	883	967	019	081	—
479	539	581	661	713	791	857	889	991	033	103	—

9. *The Equation of Secular Inequalities.* *By* T. J. I'A. BROMWICH, *St. John's College, Cambridge.*

The theory of the mean motion of the perihelion and node of a planet's orbit was proved by Laplace to depend on a certain determinantal equation of degree equal to the number of planets considered. A paper has recently been published by C. V. L. Charlier ('Öfversigt af kongl. Vet.-Akad. Förhandlingar,' Stockholm, 1900, p. 1083) in which he considers the question of equal roots in this equation; the case of equal roots was regarded by Laplace as unstable. Charlier remarks that Weierstrass had proved ('Berliner Monatsberichte,' 1858, p. 207, or 'Ges. Werke,' Bd. i. p. 233) that the equation (of the same form) which appears in the theory of small oscillations about a position of equilibrium does *not* lead to instability if equal roots are present; but apparently he regards Weierstrass's investigation as not sufficient to apply in the more general problem of astronomy. Charlier then considers the astronomical case, in Weierstrass's way, supposing that equal roots do appear in Laplace's equation; but the astronomical case may be

considered as covered by Routh's[1] and Weierstrass's[2] investigations as to the stability of a state of steady motion.

Amongst other results, Charlier finds a method for reducing the disturbing function to a canonical form. As I have recently indicated[3] a process for the reduction in the more general case of any steady motion, it may be worth while to show how my method is simplified in Charlier's case. Using the notation of my own paper, Charlier's disturbing function is given by writing $b_{rs}=0$, $c_{rs}=a_{rs}$, so that

$$H_2=\tfrac{1}{2}\Sigma a_{rs}x_r x_s+\tfrac{1}{2}\Sigma a_{rs}\xi_r\xi_s \qquad (r, s=1, 2, \ldots, n)$$

where

$$a_{rs}=a_{sr}$$

and the equations of motion are

$$\frac{dx_r}{dt}=\frac{\partial H_2}{\partial \xi_r}, \quad \frac{d\xi_r}{dt}=-\frac{\partial H_2}{\partial x_r}.$$

Then the determinant which I employ

$$\begin{vmatrix} a_{11}, & a_{12}, & \ldots, & a_{1n}, & -\mu, & 0, & \ldots, & 0 \\ a_{21}, & a_{22}, & \ldots, & a_{2n}, & 0, & -\mu, & \ldots, & 0 \\ \cdots & & & & & & & \cdots \\ a_{n1}, & a_{n2}, & \ldots, & a_{nn}, & 0, & 0, & \ldots, & -\mu \\ \mu, & 0, & \ldots, & 0, & a_{11}, & a_{12}, & \ldots, & a_{1n} \\ 0, & \mu, & \ldots, & 0, & a_{21}, & a_{22}, & \ldots, & a_{2n} \\ \cdots & & & & & & & \cdots \\ 0, & 0, & \ldots, & \mu, & a_{n1}, & a_{n2}, & \ldots, & a_{nn} \end{vmatrix} = 0$$

which is readily reduced to the form

$$\begin{vmatrix} f_{11}+\mu^2, & f_{12}, & \ldots, & f_{1n} \\ f_{21}, & f_{22}+\mu^2, & \ldots, & f_{2n} \\ \cdots & & & \cdots \\ f_{n1}, & f_{n2}, & \ldots, & f_{nn}+\mu^2 \end{vmatrix} = 0$$

where $f_{rs}=a_{r1}a_{1s}+a_{r2}a_{2s}+\ldots+a_{rn}a_{ns}$, so that $f_{rs}=f_{sr}$. It follows by a theorem due to Frobenius[4] that the values of μ^2 are equal to those of $-\lambda^2$, where λ is a root of the equation

$$\begin{vmatrix} a_{11}-\lambda, & a_{12}, & \ldots, & a_{1n} \\ a_{21}, & a_{22}-\lambda, & \ldots, & a_{2n} \\ \cdots & & & \cdots \\ a_{n1}, & a_{n2}, & \ldots, & a_{nn}-\lambda \end{vmatrix} = 0$$

By another theorem due to Frobenius, the *invariant factors* of the equation in μ are *linear*, as a consequence of the linearity of those of the equation in λ. That the latter are linear was proved by Weierstrass (*l.c.*) ('Berliner Monatsberichte,' 1858, p. 215; 1868, p. 336). It follows that if $\lambda=a_1, a_2, \ldots, a_n$ are the (real) roots of the equation in λ; then $\mu=\pm ia_1, \pm ia_2, \ldots, \pm ia_n$ are the roots of the equation in μ (of which any number may be equal); and so the method of § 3 of my paper already quoted can be applied to bring H_2 to the form

$$i\Sigma a_r x_r'\xi_r' \qquad (r=1, 2, \ldots, n)$$

the canonical equations of motion being unaltered. In this form the reality of

[1] *Adams Prize Essay*, 1877, *Stability of Motion*; *cf.* Thomson and Tait, *Natural Philosophy*, art 343 *m*.

[2] *Berliner Monatsberichte*, 1879, p. 430.

[3] *Proc. Lond. Math. Soc.*, vol. xxxii. 1900, p. 197 (see also p. 325).

[4] Crelle's *Journal f. d. Math.*, Bd. lxxxiv. 1878, p. 1 (see p. 11, *Satz* iii. and p. 25, *Satz* v.)

the results is not easily seen, and so we may use the equivalent form (given on p. 216 of my paper)

$$\tfrac{1}{2}\Sigma a_r(x''^2_r + \xi''^2_r)$$

which is Charlier's form. It is perhaps worth while to remark that Jordan's method[1] can be applied in this case, and without the use of imaginary quantities.

10. *The Puiseux Diagram and Differential Equations.*[2] *By* R. W. H. T. Hudson, *B.A, Fellow of St. John's College, Cambridge.*

The paper is concerned with the approximate solution of ordinary differential equations in the neighbourhood of *singular points*, and commences with a brief description of the method of using a diagram of unit points (squared paper) similar to that introduced by Puiseux for the case of algebraic functions. This method, which was first applied to differential equations by Briot and Bouquet, and extended by Fine, is shown to be capable of supplying information as to the existence of infinitudes of non-regular integrals which are usually obtained by purely analytical processes. The essential thing to notice is that a first approximation to a solution may be obtained, not only from a *side* of the 'polygon,' but also from a *corner*, provided that the corner arise as a marked point from two or more terms in the differential equation, and two inequalities be satisfied, expressing a certain geometrical condition. The case of a differential equation of the first order and a point on the discriminant locus at which the integral curves have *not* a cusp is a good example, and shows the existence of a *nerml* may be predicted from an inspection of the diagram. The case of solutions in series which at some stage introduce logarithms is shown also to depend on corner points arising from more than one term.

11. *The Fourier Problem of the Steady Temperatures in a thin Rod.* *By* James W. Peck.

The solution $v = V\exp\left(-x\sqrt{\frac{cp}{ks}}\right)$ is considered from the point of view of the isothermals and tubes of flow. The result so got appears to contradict the initial hypothesis of lateral radiation; and it is pointed out that the difficulty cannot be evaded by considering the radiation negligible, for this nullifies the initially chosen equation of heat-flow. Explanation is found in the approximate nature of the solution, and two necessary conditions of the approximation are worked out as follows: defining the ratio $e : k$ as the thermal length modulus (L)—also specified physically and taking a as the radius and l the length of the rod, we must have (i.) the ratio $\frac{a}{2}$: L small; (ii.) the ratio $\sqrt{\frac{La}{2}}$: l small. For experimental purposes the first ratio should not exceed $\frac{1}{200}$, but the second need only be smaller than about $\frac{1}{8}$. Illustrations of the neglect of these conditions are drawn from the experiments of Despretz and of Wiedemann and Franz. Numerical values of L are given for a range of substances, and the limits between which the Fourier result is applicable are pointed out. A solution having a higher degree of approximation than the Fourier result is then derived from the Bessel function solution, viz.

$$\frac{2V}{8}\left[\lambda_1^2\epsilon^{-\lambda_2 x}\left(1-\frac{\lambda_2^2 r^2}{4}\right)-\lambda_2^2\epsilon^{-\lambda_1 x}\left(1-\frac{\lambda_1^2 r^2}{4}\right)\right]$$

[1] Liouville's *Journal de Math.* (2), t. xix. 1874, p. 35 (§§ 5–8). References to Kronecker's methods of reduction and to other methods will be found in my paper already quoted.

[2] The paper is published in the *Proceedings of the London Mathematical Society*, vol. xxxiv.

and it is shown that the isothermals may in certain defined cases be taken as the axial paraboloids of revolution

$$r^2 = 2\sqrt{2La}\{ [illegible] \sqrt{\tfrac{La}{2}} \log. (La [illegible] (L + aV)\}$$

and the lines of flow as the logarithmic curves

$$y = A [illegible]$$

Drawings of the curves and numerical examples are given in illustration of these results.

12. *Note on the Potential of a Surface Distribution.* *By* T. J. I'A. Bromwich, *St. John's College, Cambridge.*

The problem is the determination of the discontinuities (at the surface) of the second differential coefficients of the potential: the results are familiar, but the method seems easier than any other I am acquainted with. The same method has been used by Weingarten ('Acta Mathematica,' Bd. x. 1887, p. 303; 'Archiv d. Math. u. Phys.' (3), Bd. i. 1901, p. 27) to find the discontinuities in the second differential coefficients of the potential of an attracting mass at the boundary of the space which it occupies; also for some kinematical conclusions in connection with vortex motion.

Take the origin on the surface at an ordinary point of the surface and let the axis of z be normal to the surface. If the surface is closed the positive direction of z will be from the inside towards the outside of the surface; if the surface is not closed the direction of z can be taken arbitrarily. The side for which z is positive will be denoted by the suffix 0, the other side by the suffix 1. The equation to the surface then takes the form (near the origin)

$$z = \tfrac{1}{2}(ax^2 + 2hxy + by^2) + \ldots$$

Let σ be the surface density at (x, y, z), supposed to be finite, continuous, and differentiable, and let s be the value of σ at the origin, s_x, s_y, s_z being the first differential coefficients there. Then we may write

$$\sigma = s + xs_x + ys_y + zs_z + \epsilon r$$

where

$$r^2 = x^2 + y^2 + z^2$$

and ϵ may be made as small as we please by sufficiently diminishing r.
The potentials on the two sides of the surface are denoted by V_0, V_1, and we write

$$u_x = \frac{\partial V_1}{\partial x} - \frac{\partial V_0}{\partial x},\ u_{xx} = \frac{\partial^2 V_1}{\partial x^2} - \frac{\partial^2 V_0}{\partial x^2},\ u_{xy} = \frac{\partial^2 V_1}{\partial x \partial y} - \frac{\partial^2 V_0}{\partial x \partial y},\ \&c.$$

where the values of the differential coefficients are to be taken at the origin. Thus

$$\frac{\partial V_1}{\partial x} - \frac{\partial V_0}{\partial x} = u_x + xu_{xx} + yu_{xy} + zu_{xz} + \epsilon_x' r,\ \&c.$$

where the quantities ϵ' may be made as small as we please by sufficiently diminishing r.

But at points on the given surface

$$z = \tfrac{1}{2}(ax^2 + 2hxy + by^2) + \ldots$$

and so we may write

$$\sigma = s + xs_x + ys_y + \epsilon'' r,\quad \frac{\partial V_1}{\partial x} - \frac{\partial V_0}{\partial x} = u_x + xu_{xx} + yu_{xy} + \epsilon_x''' r,\ \&c.$$

Now, by the theory of the potential of a surface density, as given in the ordinary books on potential,

$$\frac{\partial V_1}{\partial x} - \frac{\partial V_0}{\partial x} = 4\pi\sigma l, \quad \frac{\partial V_1}{\partial y} - \frac{\partial V_0}{\partial y} = 4\pi\sigma m, \quad \frac{\partial V_1}{\partial z} - \frac{\partial V_0}{\partial z} = 4\pi\sigma n,$$

where l, m, n are the direction cosines of the normal to the surface (drawn from the side $z<0$ towards the side $z>0$).

Here we may write

$$l = -(ax + hy) + \epsilon_x r, \quad m = -(hx + by) + \epsilon_y r, \quad n = 1 + \epsilon r,$$

and so we have

$$u_x + xu_{xx} + yu_{xy} + \epsilon_x''' r = 4\pi(s + xs_x + ys_y + \epsilon'' r)\left[-(ax + hy) + \epsilon_x r\right]$$
$$u_y + xu_{xy} + yu_{yy} + \epsilon_y''' r = 4\pi(s + xs_x + ys_y + \epsilon'' r)\left[-(hx + by) + \epsilon_y r\right]$$
$$u_z + xu_{xz} + yu_{yz} + \epsilon''' r = 4\pi(s + xs_x + ys_y + \epsilon'' r)\left[1 + \epsilon_z r\right]$$

As these hold for *all* values of x, y, for which r is less than some assignable quantity, we have the results

$$\begin{aligned} u_{xx} &= -4\pi as \quad , \quad u_{xz} = 4\pi s_x \\ u_{yy} &= -4\pi bs \quad , \quad u_{yz} = 4\pi s_y \\ u_{zz} &= +4\pi(a + b)s \quad , \quad u_{xy} = -4\pi hs \end{aligned}$$

where the value of u_{zz} is determined by the fact that

$$u_{xx} + u_{yy} + u_{zz} = (\nabla^2 V_1 - \nabla^2 V_0) \text{ at the origin}$$
$$= 0$$

Since

$$a + b = \frac{1}{\rho_1} + \frac{1}{\rho_2}$$

where ρ_1, ρ_2 are the principal radii of curvature of the surface, it follows that

$$u_{zz} = 4\pi s\left(\frac{1}{\rho_1} + \frac{1}{\rho_2}\right)$$

is independent of the directions of the axes of x, y, as might be expected. A special case of this, when the surface is an equipotential, was given first by Green, ('Essay,' § 8). These results agree with those given by Korn ('Lehrbuch der Potentialtheorie,' Bd. i. p. 50), and Poincaré ('Potentiel Newtonien,' p. 251), when allowance is made for the simplification introduced by using the axes selected above.

13. *The Applications of Fourier's Series to Mathematical Physics.* *By* H. S. Carslaw, *D.Sc.*

In the problem of conduction of heat when the solution is given by the infinite series

$$v = \Sigma a_n \sin nx e^{-Kn^2t},$$

where

$$a_n = \frac{2}{\pi}\int_0^\pi f(x') \sin nx' dx',$$

the presence of the factor e^{-Kn^2t} preserves the convergency of the series when differentiated term by term.

In the problems of transverse vibrations of strings where the solution is given by

$$v = \Sigma a_n \sin nx \cos nat$$

this convergency factor is not present. The paper called attention to two matters connected with this solution:—

(1) The series which are used—when the string starts from a position of rest with sharp corners—is not capable of differentiation twice with regard to x and t.

(2) The equation $\frac{d^2y}{dt^2} = a^2\frac{d^2y}{dx^2}$, being obtained on the assumption that the string forms a curve without sharp corners, cannot without discussion be applied to these cases.

Department II.—Physics.

The following Reports and Papers were read:—

1. *Report on Underground Temperature.*—See Reports, p. 64.

2. *Report on Seismological Investigation.*—See Reports, p. 40.

3. *On the Seasonal Variation of the Atmospheric Temperature of the British Isles and its Relation to Wind-direction. By* W. N. Shaw, *M.A., F.R.S., and* R. Waley Cohen, *B.A.*[1]

If the twenty-five-year means of temperature for each day of the year at the four principal stations of the British Meteorological Office be plotted the curves do not exhibit a smooth run, but show a number of irregularities—often of considerable magnitude. It is thus difficult to assign any specific number as the normal mean temperature for a particular day, and the immediate object of the work described below was to obtain a smooth curve to which the actual observed temperature of any day might be referred and to study its characteristics. The curves of actual daily means were first compared with simple harmonic curves having an annual period, a maximum about July 21, and the same area as the irregular curves. The comparison at once disclosed a lag of spring and an acceleration of autumn, and a corresponding exaggeration of the summer maximum and moderation of the winter minimum. These features, being essentially characteristic of the combination of a first and second order sine curve with a maximum at the same epoch, suggested the idea of combining two such curves to obtain a normal curve of reference. These combined curves give very satisfactory smoothed curves for the whole year for each station, and show that the periodic variations of atmospheric temperature at Kew may be very approximately represented by the summation of two effects, one of which corresponds to a sine curve with an annual period and an amplitude of 12°·04 F. and the other to a sine curve with a semi-annual period and an amplitude of 1°·4 F. Similar statements with similar numerical magnitudes are true of the other stations. This result has been confirmed analytically.

The curves of daily mean atmospheric temperature have been harmonically analysed for each of the stations, and the values of the harmonic coefficients have been determined in the Meteorological Office by means of Sir R. Strachey's formula.[2] In each case there is a second order curve whose amplitude is about one-eighth of that of the first order, and the amplitudes of the curves of higher order are so small as to be negligible. The first order curve has a maximum at a date which varies at the four stations from July 23 to August 1, and the second order curve has maxima which vary from January 28 to February 3, and July 30

[1] See *Proc. Royal Soc.*
[2] *Proc. Royal Soc.*, vol. xlii. pp. 61–79.

to August 5 respectively, and minima about the end of April and October respectively.

Assuming the first order curve to represent the primary solar effect, the purpose of this investigation has been to ascertain the nature and cause of the second order effect.

Analysis of the temperature at Vienna shows that it does not exist there either to the same extent or at the same epoch. At Agra there is a second order effect of considerable magnitude, but at an entirely different epoch, and hence in no way analogous to the effect in the British Isles. The effect is thus shown to be meteorological and not planetary.

The effect was first studied for Kew. Its cause was sought in the effects and relative frequency of occurrence of cyclonic and anticyclonic weather. For this purpose the mean temperatures of cyclonic days for each month throughout the year during the five years 1876–1880, and of anticyclonic days during the same period, were separately calculated, and curves were plotted whose ordinates are proportional to the difference between these values and the mean of the ordinates of the first order curve for each month. Both these curves show the main characteristics of the second order curve, and the curve of difference of temperature between cyclonic and anticyclonic weather shows no sign of it. Moreover, by multiplying the percentage of difference of frequency of cyclonic and anticyclonic weather for each month by the difference in temperature, the total effect of type of weather on temperature is obtained, and its curve shows that it does not in any respect resemble the second order effect. It is concluded that although the second order effect has a meteorological origin the type of the weather plays no part in causing it.

The effect of wind direction was next examined for the nine-year period 1876–1884. The mean temperatures of the air during the prevalence of barometric gradients towards each of eight points of the compass in each month were separately calculated, and curves of divergence from the first harmonic component were drawn for each wind (taken as being at right angles to the gradient) in the same way as for the cyclonic and anticyclonic curves. Each of these curves shows at least some characteristic of the second order curve; but on summing them all together a curve is obtained which differs somewhat from the total curve of divergence from first order curve values.

The effect is largely accounted for as the combined effect of the seasonal variations in temperature of the several winds, and when this part is eliminated the remainder must be attributed to the relative frequency of winds of different temperature. To show this more clearly the winds were grouped together. The mean temperature divergence of east winds is $-3^\circ{\cdot}1$ F.; of north-east winds $-4^\circ{\cdot}0$ F.; and of north winds $-3^\circ{\cdot}5$ F. These winds were grouped as 'cold' winds. Similarly the north-west and south-east winds, whose mean divergences are only $-0^\circ{\cdot}6$ F. and $-0^\circ{\cdot}7$ F. respectively, were grouped as 'temperate' winds, and the west, south-west, and south winds, whose mean divergences are $+1^\circ{\cdot}7$ F., $+2^\circ{\cdot}2$ F., and $+2^\circ{\cdot}5$ F. respectively, were grouped as 'warm' winds. Temperature curves were drawn for each of these groups analogous to the curves for the separate winds. Each curve again shows a general resemblance to the second order curve, but it is noticeable that the October-November minimum is especially prominent in the curve for the temperate winds. The mean frequencies of occurrence of these groups in each month during the nine years were also calculated and expressed as a percentage of the total number of days; the results were plotted on curves whose ordinates are proportional to these percentage frequencies.

The frequency curve for 'cold' winds shows a very remarkable maximum frequency in May and a small maximum in November.

The frequency curve for warm winds shows minima at these times and maxima in February and August, and the frequency curve for temperate winds, which become distinctly colder in October-November, shows a very high maximum at the end of October. At that time the temperature of these winds is much below the average relative value, and thus the small maximum of the curve of the cold

winds at that time is reinforced by the seasonal coldness of the more prevalent winds.

As an example of the results derived from the inquiry it may be mentioned that the minimum of the second order effect at the end of April may be attributed to the relative frequency of 'cold' winds and the relative coldness of all winds at that period, while the corresponding minimum at the end of October must be assigned to the relative frequency of 'temperate' winds and the comparative coldness of those winds at that time of the year.

The second order effect is apparent in a single year's observations, and has, with few exceptions, a larger amplitude in the analysis of the temperature curve of a single year than in that of a mean curve of a number of years. The amplitude for a single year may be as much as 3°, or a quarter of the amplitude of the whole annual variation.

A similar effect is found in the variation of magnitude of the barometric gradient between London and Valencia, and London and Aberdeen. It is probable that this periodic variation in pressure plays some part in causing the similar variation in temperature.

A similar effect is also found in the temperature variation of the sea water at stations surrounding these islands, and the atmospheric effect is probably connected with this.

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4. *On the Effect of Sea Temperature upon the Seasonal Variation of Air Temperature of the British Isles.* By W. N. Shaw, *M.A.*, *F.R.S.*[1]

The paper describes an attempt to utilise the mode of geometrical composition and resolution of sine curves of the same period to resolve the principal seasonal variations of temperature at a station into constituents, which may be called the primary solar constituent, and the constituent due to the surroundings of land and sea respectively.

The analysis of atmospheric temperature shows that there is a considerable lag in the occurrence of the seasonal variations of temperature at coast stations as compared with inland stations, and a still greater lag in the variations of temperature in the sea itself.

The variation in sea temperature is regarded as a periodic cause of variation of atmospheric temperature at coast stations, the effect of which is periodic in the same period, and may be compounded with the primary solar effect to give the resultant seasonal variation.

The effects of these curves of equal period may be represented in magnitude by the numerical value of the amplitudes of the first order curves of the respective temperature variations, and they may be compounded geometrically by means of a triangle whose sides are proportional to these amplitudes, and are inclined at angles corresponding to the relative epochs of the curves. In such a triangle the following elements are known:—

1. A side proportional to the observed amplitude at the station.
2. The difference in epoch between the primary solar cause and the resultant, *i.e.*, the angle between the sides proportional to the amplitudes of the primary solar and of the resultant effects.
3. The angle between the sides proportional to the marine and the primary solar effect.

By assuming the primary solar effect to be the same for places in the same latitude it would thus be possible to analyse seasonal variation of temperature at any place into its elements, and an example is given of this analysis in the case of Kew. A point of some interest arising out of this is the lag in the seasons at sea-coast stations, showing that not only the autumn and winter are late at the sea-coast, but also the spring, so that an early spring is to be sought inland.

[1] See *Proc. Royal Soc.*

Another point of interest is the effect of the sea, which is not, as is generally supposed, actually to decrease the amplitude of annual temperature oscillation, but to increase it, although to a less extent than a corresponding surrounding area of land. Thus at Nertchinski-Zavod, in Siberia, the effect (calculated as above) of the secondary cause, *i.e.*, the surrounding land, on annual temperature variation has an amplitude of 55° F.; whilst at Kew, in the same latitude, the effect of the surrounding land and sea has only an amplitude of 8°·3 F. The figures for sea temperature are inadequate for effective numerical analysis, but they suggest a possibility of arriving on these lines at a definite comparison of inland and marine climates.

5. *A New Point of View about Gravitation, and a proposed Experiment. By* Dr. V. Crémieu.

We know perfectly well the quantitative law of gravitation, but we have no idea of the mechanism of the attraction.

Several attempts have been made to explain gravitation by the presence of a medium, but, I believe, all without success. Some learned men, too, had the idea of finding by experiment whether the propagation of attraction was instantaneous or not; but, as far as I know, no physical experiment was ever tried.

Whenever a system is in equilibrium every attempt to disturb that equilibrium will introduce new forces into the system, which will act against this disturbance of equilibrium.

There are many examples: heating of gases by compression, increase of resistance of metals with temperature, and consequently, when they are submitted to an electromotive force; and, moreover, the law of Lenz in induction.

I thought that gravitation must very likely follow that universal law.

If, for instance, we consider the two bodies A and B in equilibrium, we can imagine that there is a 'flux of attraction' between them. Let us move A very quickly: this motion will produce a sudden variation in that flux, and a reaction will take place in the system at that moment which will work against the motion communicated to A.

A few months ago I described in the 'Comptes Rendus' a new very sensitive kind of balance which gives us an easy and direct way of verifying that idea.

This balance is made in the following manner: a very light tube of aluminium is horizontally suspended by a silk thread, the two bent parts of which form an angle of about 120°.

At one end of this tube is fixed a small sphere of platinum weighing about three grammes. At the other end is a permanent magnet suspended by a silk thread; the weight of this magnet is three or four milligrammes lighter than that of the sphere.

A coil is fixed on the support of the apparatus, and the silk thread bearing the permanent magnet coincides with the axis of that coil.

On sending a current through it in the proper direction a repulsion between the fixed coil and the permanent magnet will be established. That is the repulsion which will be used instead of weights.

I have constructed several of these balances for use as galvanometers or electrometers. The measured accuracy of one was as follows:

It gives, at a distance of two metres, a deviation of 12 millimetres for a current of 10^{-9} amperes, which corresponds on the movable magnet to a force of 3×10^{-5} dynes. This is the maximum obtained as yet. But I can easily obtain the 10^{-4} of a dyne; and I hope, with the long arm constructed for my gravitation experiment, to each about the 10^{-6} of a dyne.

Now, with a convenient current, let us produce equilibrium between the magnet and the sphere. We will record it by the position of a spot of light reflected by a mirror. If, then, we bring near to the sphere a heavy sphere of lead, there will be an attraction between them; we can equilibrate it by increasing conveniently the current in the coil.

If now we drop the heavy sphere of lead we shall have the sudden variation required for the experiment.

If my idea is right we shall observe at that same moment an impulsion of the spot of light on the scale in the direction of the motion—that is to say, in a direction contrary to that which would be observed if the assumed effect does not exist.

The apparatus for making the experiment is now ready, and I hope to obtain results before long.

I will point out that astronomical observations cannot answer this question because in the motions of the planets there are only very small changes of the 'flux of gravitation'; and, besides, the distances are enormous. Moreover, as these changes would be always reversed in the course of a complete revolution, their very small effects would neutralise one another.

6. *A Discussion on the proposed New Unit of Pressure, opened by a Paper by* Dr. C. E. Guillaume.—For Dr. Guillaume's Paper see Reports, p. 71.

7. *The Michelson-Morley Effect. By* W. M. Hicks, *F.R.S.*

In the theory of this experiment, as usually presented, no account is taken of the alteration in wave length produced by reflection from a moving surface, nor of the alteration in the direction of incidence as the drift alters, when the source of light is fixed to the apparatus. When this is done it follows that the phenomena to be expected are not precisely the same as those usually supposed, and in certain cases the displacement of the fringes is subject to a quite different law. The two sets of interfering waves, when there is drift, have not the same wave length in space, although their *apparent* frequencies at any point moving with the apparatus are equal. Consequently interference fringes are produced on a screen which is fixed to the apparatus, and these fringes are displaced a certain number of bands when the apparatus drifts. Usually, however, the fringe is observed by an optical apparatus which produces an image on the retina. But the two interfering pencils from any point of the actual fringe, when they arrive at the retina, have a different phase-difference from that at the original point Consequently the image of the central bright line will not itself be a bright line. The central bright band on the retina will be the optical image of another point on the original, and the fringe-image shows the original one displaced by a certain amount which alters with the drift. The observed displacement is therefore the resultant of two others, one of which may in certain circumstances quite mask the other. Supposing the drift of the apparatus to be comparable with that of the earth's orbital motion—say 10^{-4} times that of light—it was shown to be possible that in Michelson's actual experiment the arrangements were such that the effect he expected was quite masked by the other.

8. *The Law of Radiation. By* Dr. J. Larmor, *F.R.S.*

9. *Radiation of Heat and Light from a Heated Solid Body. By* Dr. J. T. Bottomley, *F.R.S.*

In this paper an account is given of recent experiments on radiation of heat and light from a heated solid body commencing with the very lowest temperature at which a heated body becomes visible and proceeding to temperatures approaching white heat. The experiments were made on pairs of platinum strips specially prepared for the author by Messrs. Johnson & Matthey. The strips were 1½ mm. broad, and extremely thin. One of each pair was highly polished, and the other was coated with lampblack. The pairs of strips

were contained in similar glass tubes, which were connected together by end tubes, one of which was connected to a Sprengel pump, and by means of the Sprengel pump a very high vacuum was obtained, so that the energy lost was entirely due to radiation; the amount of heat lost by convection being negligible. The lowest temperature at which the strip becomes visible in a darkened chamber to an observer who has remained in the dark for some time in order that his eyes may attain perfect sensitiveness is about 400° C. At this temperature the blackened strip loses nearly seven times as much energy as the polished strip. As the temperature rises the ratio seems to fall, while the light given off passes to dull red, then to cherry red, and finally to bright red approaching white heat.

Experiments are also referred to, of an older date, in which pairs of wires, one polished and the other sooted, were compared at the same temperature (inferred from the resistance of the wires).

It is concluded from all these experiments that the production of light is vastly more economical when the surface of the light-giving body is bright and highly polished than when it is dull or coated with lampblack.

TUESDAY, SEPTEMBER 17.

The Section was divided into two Departments.

DEPARTMENT I.—PHYSICS.

The following Papers were read :—

1. *On the Clustering of Gravitational Matter in any part of the Universe. By* LORD KELVIN, *G.C.V.O., F.R.S.*

Gravitational matter, according to our ideas of universal gravitation, would be all matter. Now, is there any matter which is not subject to the law of gravitation? I think I may say with absolute decision that there is. We are all convinced, with our President, that ether is matter, but we are forced to say that the properties of molar matter are not to be looked for in ether as generally known to us by action resulting from force between atoms and matter, ether and ether, and atoms of matter and ether. Here I am illogical when I say between matter and ether, as if ether were not matter. It is to avoid an illogical phraseology that I use the title 'gravitational matter.' Many years ago I gave strong reason to feel certain that ether was outside the law of gravitation. We need not absolutely exclude, as an idea, the possibility of there being a portion of space occupied by ether beyond which there is absolute vacuum—no ether and no matter. We admit that that is something that one could think of; but I do not believe any living scientific man considers it in the slightest degree probable that there is a boundary around our universe beyond which there is no ether and no matter. Well, if ether extends through all space, then it is certain that ether cannot be subject to the law of mutual gravitation between its parts, because if it were subject to mutual attraction between its parts its equilibrium would be unstable, unless it were infinitely incompressible. But here, again, I am reminded of the critical character of the ground on which we stand in speaking of properties of matter beyond what we see or feel by experiment. I am afraid I must here express a view different from that which Professor Rücker announced in his Address, when he said that continuity of matter implied absolute resistance to condensation. We have no right to bar condensation as a property of ether. While admitting ether not to have any atomic structure, it is postulated as a material which performs functions of which we know something, and which may have properties allowing it to perform other functions

of which we are not yet cognisant. If we consider ether to be matter, we postulate that it has rigidity enough for the vibrations of light, but we have no right to say that it is absolutely incompressible. We must admit that sufficiently great pressure all round could condense the ether in a given space, allowing the ether in surrounding space to come in towards the ideal shrinking surface. When I say that ether must be outside the law of gravitation, I assume that it is not infinitely incompressible. I admit that if it were infinitely incompressible, it might be subject to the law of mutual gravitation between its parts; but to my mind it seems infinitely improbable that ether is infinitely incompressible, and it appears more consistent with the analogies of the known properties of molar matter, which should be our guides, to suppose that ether has not the quality of exerting an infinitely great force against compressing action of gravitation. Hence, if we assume that it extends through all space, ether must be outside the law of gravitation—that is to say, truly imponderable. I remember the self-complacent compassion with which sixty years ago—I myself, I am afraid—and most of the teachers of that time looked upon the ideas of the elderly people who went before us, who spoke of 'the imponderables.' I fear that in this, as in a great many other things in science, we have to hark back to the dark ages of fifty, sixty, or a hundred years ago, and that we must admit there is something which we cannot refuse to call matter, but which is not subject to the Newtonian law of gravitation. That the sun, stars, planets, and meteoric stones are all of them ponderable matter is true, but the title of my paper implies that there is something else. Ether is not any part of the subject of this paper; what we are concerned with is gravitational matter, ponderable matter. Ether we relegate, not to a limbo of imponderables, but to distinct species of matter which have inertia, rigidity, elasticity, compressibility, but not heaviness. In a paper I have already published I gave strong reasons for limiting to a definite amount the quantity of matter in space known to astronomers. I can scarcely avoid using the word 'universe,' but I mean our universe, which may be a very small affair after all, occupying a very small portion of all the space in which there is ponderable matter.

Supposing a sphere of radius $3{\cdot}09.10^{16}$ kilometres (being the distance at which a star must be to have parallax $0''{\cdot}001$) to have within it, uniformly distributed through it, a quantity of matter equal to one thousand million times the sun's mass, the velocity acquired by a body placed originally at rest at the surface would, in five million years, be about 20 kilometres per second, and in twenty-five million years would be 108 kilometres per second (if the acceleration remained sensibly constant for so long a time). Hence, if the thousand million suns had been given at rest twenty-five million years ago, uniformly distributed throughout the supposed sphere, many of them would now have velocities of 20 or 30 kilometres per second, while some would have less and some probably greater velocities than 108 kilometres per second; or, if they had been given thousands of million years ago at rest so distributed that now they were equally spaced throughout the supposed sphere, their mean velocity would now be about 50 kilometres per second.[1] This is not unlike the measured velocities of stars, and hence it seems probable that there might be as much matter as one thousand million suns within the distance $3{\cdot}09.10^{16}$ kilometres. The same reasoning shows that ten thousand million suns in the same sphere would produce velocities far greater than the known star velocities, and hence there is probably much less than ten thousand million times the sun's mass in the sphere considered. A general theorem discovered by Green seventy-three years ago regarding force at a surface of any shape, due to matter (gravitational, or ideal electric, or ideal magnetic) acting according to the Newtonian law of the inverse square of the distance, shows that a non-uniform distribution of the same total quantity of matter would give greater velocities than would the uniform distribution. Hence we cannot, by any non-uniform distribution of matter within the supposed sphere of $3{\cdot}09.10^{16}$ kilometres radius, escape from the conclusion limiting the total amount of the matter within it to something like one thousand million times the sun's mass.

[1] *Phil. Mag.*, August 1901, pp. 169, 170.

If we compare the sunlight with the light from the thousand million stars, each being supposed to be of the same size and brightness as our sun, we find that the ratio of the apparent brightness of the star-lit sky to the brightness of our sun's disc would be $3{\cdot}87.10^{-13}$. This ratio[1] varies directly with the radius of the containing sphere, the number of equal globes per equal volume being supposed constant; and hence to make the sum of the apparent area of discs 3·87 per cent. of the whole sky, the radius must be $3{\cdot}09.10^{27}$ kilometres. With this radius light would take $3\frac{1}{4}.10^{14}$ years to travel from the outlying stars to the centre. Irrefragable dynamics proves that the life of our sun as a luminary is probably between fifty and 100 million years; but to be liberal, suppose each of our stars to have a life of 100 million years as a luminary, and it is found that the time taken by light to travel from the outlying stars to the centre of the sphere is three and a quarter million times the life of a star. Hence it follows that to make the whole sky aglow with the light of all the stars at the same time the commencements of the stars must be timed earlier and earlier for the more and more distant ones, so that the time of the arrival of the light of every one of them at the earth may fall within the durations of the lights of all the others at the earth. My supposition as to uniform density is quite arbitrary; but nevertheless I think it highly improbable that there can be enough of stars (bright or dark) to make a total of star-disc area more than 10^{-12} or 10^{-11} of the whole sky.

To help to understand the density of the supposed distribution of 1,000 million suns in a sphere of $3{\cdot}09.10^{16}$ kilometres radius, imagine them arranged exactly in cubic order, and the volume per sun is found to be $123{\cdot}5.10^{39}$ cubic kilometres, and the distance from one star to any one of its six nearest neighbours would be $4{\cdot}98.10^{13}$ kilometres. The sun seen at this distance would probably be seen as a star of between the first and second magnitude; but supposing our 1,000 million suns to be all of such brightness as to be stars of the first magnitude at distance corresponding to parallax 1″·0, the brightness at distance $3{\cdot}09.10^{16}$ kilometres would be one one-millionth of this; and the most distant of our stars would be seen through powerful telescopes as stars of the sixteenth magnitude. Newcomb estimated from thirty to fifty million as the number of stars visible in modern telescopes. Young estimated at 100 million the number visible through the Lick telescope. This larger estimate is only one tenth of our assumed 1,000 million masses equal to the sun, of which, however, 900 million might be either non-luminous, or, though luminous, too distant to be seen by us at their actual distances from the earth. Remark, also, that it is only for facility of counting that we have reckoned our universe as 1,000 million suns; and that the meaning of our reckoning is that the total amount of matter within a sphere of $3{\cdot}09.10^{16}$ kilometres radius is 1,000 million times the sun's mass. The sun's mass is $1{\cdot}99.10^{27}$ metric tons, or $1{\cdot}99.10^{33}$ grammes. Hence our reckoning of our supposed spherical universe is that the ponderable part of it amounts to $1{\cdot}99.10^{42}$ grammes, or that its average density is $1{\cdot}61.10^{-23}$ of the density of water.

Let us now return to the question of sum of apparent areas. The ratio of this sum to 4π, the total apparent area of the sky viewed in all directions, is given by the formula[1]: $\alpha = \frac{3N}{4}\left(\frac{a}{r}\right)^2$, provided its amount is so small a fraction of unity that its diminution by eclipses, total or partial, may be neglected. In this formula, N is a number of globes of radius a uniformly distributed within a spherical surface of radius r. For the same quantity of matter in N′ globes of the same density, uniformly distributed through the same sphere of radius r, we have $\frac{N'}{N} = \left(\frac{a}{a'}\right)^3$ and therefore $\frac{\alpha'}{\alpha} = \frac{a}{a'}$. With $N = 10^9$, $r = 3{\cdot}09.10^{16}$ kilometres; and a (the sun's radius) $= 7.10^5$ kilometres; we had $\alpha = 3{\cdot}87.10^{-13}$. Hence $a' = 7$ kilometres gives $\alpha' = 3{\cdot}87.10^{-8}$; and $a'' = 1$ centimetre gives $\alpha'' = 1/36{\cdot}9$. Hence if the whole mass of our supposed universe were reduced to globules of density 1·4 (being the sun's mean density), and of 2 centimetres diameter, distributed uniformly through a sphere of $3{\cdot}09.10^{16}$ kilometres radius, an eye at the

[1] *Phil. Mag.*, August 1901, p. 175.

centre of this sphere would lose only 1/36·9 of the light of a luminary outside it! The smallness of this loss is easily understood when we consider that there is only one globule of 2 centimetres diameter per 360,000,000 cubic kilometres of space, in our supposed universe reduced to globules of 2 centimetres diameter. Contrast with the total eclipse of the sun by a natural cloud of water spherules, or by the cloud of smoke from the funnel of a steamer.

Let now all the matter in our supposed universe be reduced to atoms (literally brought back to its probable earliest condition). Through a sphere of radius r let atoms be distributed uniformly in respect to gravitational quality. It is to be understood that the condition 'uniformly' is fulfilled if equivoluminal globular or cubic portions, small in comparison with the whole sphere, but large enough to contain large numbers of the atoms, contain equal total masses, reckoned gravitationally, whether the atoms themselves are of equal or unequal masses, or of similar or dissimilar chemical qualities. As long as this condition is fulfilled, each atom experiences very approximately the same force as if the whole matter were infinitely fine-grained, that is to say, utterly homogeneous.

Let us therefore begin with a uniform sphere of matter of density ρ, gravitational reckoning, with no mutual forces except gravitation between its parts, given with every part at rest at the initial instant; and let it be required to find the subsequent motion. Imagining the whole divided into infinitely thin concentric spherical shells, we see that every one of them falls inwards, as if attracted by the whole mass within it collected at the centre. Hence our problem is reduced to the well-known students' exercise of finding the rectilinear motion of a particle attracted according to the inverse square of the distance from a fixed point. Let x_0 be the initial distance, $\frac{4\pi\rho}{3}x_0^3$ the attracting mass, v and x the velocity and distance from the centre at time t. The solution of the problem for the time during which the particle is falling towards the centre is

$$\tfrac{1}{2}v^2 = \frac{4\pi\rho}{3}x_0^3\left(\frac{1}{x}-\frac{1}{x_0}\right)$$

and

$$= \sqrt{\frac{3}{8\pi\rho}}\left(\frac{\pi}{2}-\theta+\tfrac{1}{2}\sin\ 2\theta\right) = \frac{\pi}{2}\sqrt{\frac{3}{8\pi\rho}}\left[1-\frac{2\theta}{\pi}\left(1-\frac{\sin 2\theta}{2\theta}\right)\right]$$

where θ denotes the acute angle whose sine is $\sqrt{\frac{x}{x_0}}$. This shows that the time of falling through any proportion of the initial distance is the same whatever be the initial distance; and that the time (which we shall denote by T) of falling to the centre is $\tfrac{1}{2}\pi\sqrt{\frac{3}{8\pi\rho}}$. Hence in our problem of homogeneous gravitational matter given at rest within a spherical surface and left to fall inwards, the augmenting density remains homogeneous, and the time of shrinkage to any stated proportion of the initial radius is inversely as the square root of the density.

To apply this result to the supposed spherical universe of radius $3{\cdot}09.10^{16}$ kilometres, and mass equal to a thousand million times the mass of our sun, we find the gravitational attraction on a body at its surface gives acceleration of $1{\cdot}37.10^{-13}$ kilometres per second per second. This therefore is the value of $\frac{4\pi\rho}{3}x_0$, with one second as the unit of time and one kilometre as the unit of distance; and we find $T = 52{\cdot}8.10^{13}$ seconds = 16·8 million years. Thus our formulas become

$$\tfrac{1}{2}v^2 = 1{\cdot}37.10^{-13}\,x_0\left(\frac{x_0}{x}-1\right)$$

giving

$$v = 5{\cdot}23.10^{-7}\sqrt{x_0\left(\frac{x_0}{x}-1\right)}$$

and

$$t = 52\cdot8.10^{13}\left[1 - \frac{2\theta}{\pi}\left(1 - \frac{\sin 2\theta}{2\theta}\right)\right]$$

whence, when $\sin\theta$ is very small,

$$t = 52\cdot8.10^{13}\left(1 - \frac{4\theta^3}{3\pi}\right)$$

Let now, for example, $x_0 = 3\cdot09.10^{16}$ kilometres, and $\frac{x_0}{x} = 10^7$; and, therefore, $\sin\theta = \theta = 3\cdot16.10^{-4}$; whence, $v = 291{,}000$ kilometres per second, and $t = \mathrm{T} - 7{,}080$ seconds $= \mathrm{T} - 2$ hours approximately.

By these results it is most interesting to know that our supposed sphere of perfectly compressible fluid, beginning at rest with density $1\cdot61.10^{-23}$ of that of water, and of any magnitude large or small, and left unclogged by ether to shrink under the influence of mutual gravitation of its parts, would take nearly seventeen million years to reach ·0161 of the density of water, and about two hours longer to shrink to infinite density at its centre. It is interesting also to know that if the initial radius is $3\cdot09.10^{16}$ kilometres, the inward velocity of the surface is 291,000 kilometres per second at the instant when its radius is $3\cdot09.10^9$ and its density ·0161 of that of water. If now, instead of an ideal compressible fluid, we go back to atoms of ordinary matter of all kinds as the primitive occupants of our sphere of $3\cdot09.10^{16}$ kilometres radius, all these conclusions, provided all the velocities are less than the velocity of light, would still hold, notwithstanding the ether occupying the space through which the atoms move. This would, I believe,[1] exercise no resistance whatever to uniform motion of an atom through it; but it would certainly add quasi-inertia to the intrinsic Newtonian inertia of the atom itself moving through ideal space void of ether; which, according to the Newtonian law, would be exactly in proportion to the amount of its gravitational quality. The additional quasi-inertia must be exceedingly small in comparison with the Newtonian inertia, as is demonstrated by the Newtonian proofs, including that founded on Kepler's laws for the groups of atoms constituting the planets, and movable bodies experimented on at the earth's surface.

In one thousand seconds of time after the density ·0161 of the density of water is reached, the inward surface velocity would be 305,000 kilometres per second, or greater than the velocity of light; and the whole surface of our condensing globe of gas or vapour or crowd of atoms would begin to glow, shedding light inwards and outwards. All this is absolutely realistic, except the assumption of uniform distribution through a sphere of the enormous radius of $3\cdot09.10^{16}$ kilometres, which we adopted temporarily for illustrational purpose. The enormously great velocity (291,000 kilometres per second) and rate of acceleration (13·7 kilometres per second per second) of the boundary inwards, which we found at the instant of density ·0161 of that of water, are due to greatness of the primitive radius, and the uniformity of density in the primitive distribution.

To come to reality, according to the most probable judgment present knowledge allows us to form, suppose at many millions, or thousands of millions, or millions of millions of years ago, all the matter in the universe to have been atoms very nearly at rest[2] or quite at rest; more densely distributed in some places than in others, of infinitely small average density through the whole of infinite space. In regions where the density was then greater than in neighbouring regions, the density would become greater still; in places of less density, the

[1] 'On the Motion produced in an Infinite Elastic Solid by the Motion through the Space occupied by it of a Body acting on it only by Attraction or Repulsion,' Cong. International de Physique, Paris, Volume of Reports (*Phil. Mag.*, August 1900).

[2] 'On Mechanical Antecedents of Motion, Heat, and Light,' *Brit. Assoc. Rep.*, Part 2, 1854; *Edin. New Phil. Jour.*, vol. i. 1855; *Comptes Rendus*, vol. xl. 1855; Kelvin's *Collected Math. and Phys. Papers*, vol. ii. art. lxix.

density will become less; and large regions will quickly become void or nearly void of atoms. These large void regions would extend so as to completely surround regions of greater density. In some part or parts of each cluster of atoms thus isolated, condensation would go on by motions in all directions not generally convergent to points, and with no perceptible mutual influence between the atoms until the density becomes something like 10^{-6} of our ordinary atmospheric density, when mutual influence by collisions would begin to become practically effective. Each collision would give rise to a train of waves in ether. These waves would carry away energy, spreading it out through the void ether of infinite space. The loss of energy, thus taken away from the atoms, would reduce large condensing clusters to the condition of gas in equilibrium[1] under the influence of its own gravity only, or rotating like our sun or moving at moderate speeds as in spiral nebulas, &c. Gravitational condensation would at first produce rise of temperature, followed later by cooling and ultimately freezing, giving solid bodies; collisions between which will produce meteoric stones such as we see them. We cannot regard as probable that these lumps of broken-looking solid matter (something like the broken stones used on our macadamised roads) are primitive forms in which matter was created. Hence we are forced, in this twentieth century, to views regarding the atomic origin of all things closely resembling those presented by Democritus, Epicurus, and their majestic Roman poetic expositor, Lucretius.

2. *A Discussion on Glass used for Scientific Purposes. Opened by a Paper by* Dr. R. T. Glazebrook, *F.R.S.*

3. *The Brush Grating and the Law of its Optical Action. By* John Kerr, *LL.D., F.R.S.*

Pure water is rendered slightly hazy by holding in suspension a small quantity of chemically precipitated and invisibly fine particles of Fe_3O_4; this liquid placed in a uniform and moderately strong magnetic field gives the best known example of the Brush grating. The water is understood to be traversed throughout its mass by a set of invisibly fine filaments of solid particles, all straight and parallel. When this medium is examined in the polariscope the vibrations transmitted are always perpendicular to the filaments.

The action of the Brush grating comes out in experiment as twofold: (1) a negative double refraction with filament for optic axis; (2) a selective absorption of the extraordinary ray. The phenomena are quite regular, and as pure as any that are given by good crystals, but upon a comparatively small scale of intensity. The simplest statement of the law of the action is that when light passes through the Brush grating the Fresnel vibrations parallel to the filaments are the most absorbed, and those perpendicular to the filaments the most retarded.

It is interesting, and may be useful, to compare the new medium with the numerous media known in optics as the coloured birefringent crystals; and also with Hertz's grating of parallel wires, used as a transmitter and absorber of electric waves.

4. *The Effect of Errors in Ruling on the Appearance of a Diffraction Grating. By* H. S. Allen, *M.A., B.Sc.*

If a spectroscope is adjusted to view a single spectral line, and the eye-piece of the observing telescope is removed, the diffraction grating is seen illuminated by monochromatic light; but in general the image is crossed by a number of dark bands parallel to the rulings on the grating. The bands may be better studied by focussing the observing telescope on the surface of the grating instead of on the

[1] Homer Lane, *American Journal of Science*, 1870, p. 57; Sir W. Thomson, *Phil. Mag.*, March 1887, p. 287.

slit of the collimator. The object of the paper is to explain the mode of formation of these bands.

In an absolutely perfect grating all the light going to form the spectral line of any particular order is brought to a single focus by the objective of the telescope, and the emergent cone of light is bounded by the image of the grating formed by the objective (the distance between the grating and the objective being greater than the focal length). In the case of a grating containing two rulings differing by a small amount the light from each portion will be brought to its own appropriate focus, and the two emergent cones of light will be bounded by the corresponding parts of the image of the grating. A screen placed in the position of this image would be uniformly illuminated, but if it were moved nearer to the lens the boundary between the two rulings would receive light from *both* the cones or from *neither* of them, according to the relative positions of the foci. If the screen were moved further from the lens the effect would be exactly reversed, so that a light band in one case becomes a dark band in the other.

The theoretical results, which have been verified by observation, may be summarised as follows:—

Orders on the right of the central image (the observer is supposed to be facing the grating).—Case 1. In passing from a wide to a narrow ruling in going from left to right. Focus in, light band. Focus out, dark band.

Case 2. In passing from a narrow to a wide ruling in going from left to right. Focus in, dark band. Focus out, light band.

Orders on the left of the central image.—The results just given must be reversed.

The bands disappear when the telescope is focussed exactly on the grating.

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5. *On a new Electromagnet and an Echelon Spectroscope for Magneto-optic Observations. By* Professor A. Gray, *F.R.S., and* Dr. W. Stewart.

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6. *On Resolving Power in the Microscope and Telescope. By* Professor J. D. Everett, *F.R.S.*

The author maintains, in opposition to the view put forward in standard books on the microscope, that resolving power, whether in the microscope or the telescope, depends simply on keeping down the size of the disc which, owing to diffraction, is the image formed by the objective of a luminous point of the object. The illumination of the disc diminishes from the centre outwards according to a well-known law, first worked out by Airy, becoming zero at a definite distance; but for a considerable distance within this limit the illumination is too faint to be appreciable, and the visible size of the disc therefore increases with the brightness of the luminous point which is imaged. The radius of the disc, reckoned up to the theoretical limit of zero illumination, is directly as the wave-length of the light employed, and inversely as the sine of the semivertical angle of the cone of rays which emerges from the objective. The effect of large aperture in the telescope, or of large N.A. in the microscope, is to increase the sine of this angle, and in the same proportion to increase the fineness of representation.

Dawes' results for the closeness of double stars which can be just separated by a given objective lead to the conclusion that the two discs, corresponding to the two nearly equal components of the star, can be just recognised as two when the illumination due to one at the centre of the other is about $\frac{1}{30}$ of the central illumination; and Abbe's determinations of the resolving powers of microscopical objectives, as dependent on N.A., lead to exactly the same conclusion for the microscope, an agreement which seems to have hitherto escaped attention.

Abbe's own view, as stated in the concluding sentence of his Paper to the Royal Microscopical Society (vol. i. 1881, p. 423), is:—

'The very first step of every understanding of the microscope is to abandon

the gratuitous assumption of our ancestors that microscopical vision is an imitation of macroscopical, and to become familiar with the idea that it is a thing *sui generis*.'

This view has since been somewhat toned down; but he still maintains that, in the case of such an object as a diatom, there is practically a superposition of two images, one depicting the coarse outlines and the other the fine details.[1]

It is of course legitimate to mentally divide phenomena into two classes for convenience of treatment; but Huygens' principle applies equally to the fine and the coarse parts of an object; and there is no way of obtaining true representation of fine details except by giving smallness to the discs which are the images of points, seeing that the whole image, coarse and fine parts alike, is built up of these discs.

An important point, which is merely presented as an empirical fact in books on the microscope, is the enormous benefit derived, in fine work, from employing a sub-stage condenser of high quality to throw upon the object the sharpest possible achromatic image of a limited portion of the source of illumination, an iris diaphragm, close to the condenser, being employed to assist in the limitation. The reason of the benefit is that the influence of large aperture in reducing the size of the discs which build up the image depends on the capability of mutual interference between all points of a wave-surface sent by a point of the object to the focus. Two distant portions of the surface cannot interfere, if they are derived from distinctly different parts of the source of illumination. For purposes of resolution, aperture counts only so far as it receives illumination from one and the same source. If the four quadrants of an aperture are illuminated by four separate sources, they will give, instead of a single small round spot, four larger spots partially overlapping.

A subsidiary benefit conferred by accurate focussing of the source on the object is the prevention of the spurious patterns which are formed by the interference of light sent from a single point of the source to different markings on an object.

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7. *On the Interference of Light from Independent Sources.* *By* G. JOHNSTONE STONEY, *M.A., D.Sc., F.R.S.*

In the course of an inquiry into the distribution of light by visible objects the fact has emerged that lights from independent sources can be made to interfere, whatever be their phases and states of polarisation.

The present abstract is in reference to this point. To make it sufficiently brief, it is limited to explaining the method of proof and giving one application to a case which is easily dealt with, and where the result can be verified experimentally.

The investigation starts from the admitted fact that in a transparent isotropic medium the undulation spreading outwards from each punctum, or visible point, is a train of waves of alternating electro-magnetic stresses of which the wave-fronts are surfaces that are nearly spheres, or portions of spheres, concentric with the punctum, and enlarging with the speed of light in the medium.

Electro-magnetic stresses require an expenditure of energy to produce them or to alter them, and in other respects there are analogies between the electrical events with which we shall have to deal and dynamical events. Accordingly, as we have a fuller nomenclature of dynamical than of electrical events it will be convenient to speak of changes of electro-magnetic stress as motions in the medium, of the cause of an alteration of the rate of change as a force, and so on, for this purpose employing these and other dynamical terms in a sufficiently generalised sense.

We shall also have to assume that it is legitimate to apply the principle of reversal to electrical as to dynamical events.

Let us take a definite case, and suppose that P, a punctum or small source of light, is situated at a point f in the open æther, from which it radiates light of wave

[1] *Carpenter on the Microscope*, 8th edition, p. 64.

length λ in some or in all directions. P probably acts somewhat like a Hertzian vibrator; but whatever be its *modus operandi* it is an agent which makes a disturbance in the æther and sets up what we may call turmoil in its immediate neighbourhood. This turmoil is of a special kind, its action on the æther beyond adding wave after wave to an undulation of regular waves, which advances outwards.

It is this undulation of regular waves beyond the region of turmoil that is the light radiated from P.

The æther is competent to propagate these waves forward without external aid and by reason of forces developed within itself when strained; but the turmoil in the vicinity of P requires that forces supplied by P shall co-operate with the forces developed in the medium to keep it going. If P ceased to maintain it, the turmoil would quickly disappear after expending whatever energy had been stored up in it in adding a few additional waves to the inner fringe of the great undulation travelling outwards.

Let us draw round f a tiny sphere with radius ρ, which we may call sphere ρ, just sufficiently large to include the region of turmoil. In the case of light, one or two wave lengths is a sufficient radius for this sphere, since beyond that short distance the events in the æther do not differ sensibly from regular wave-motion.

P, which emits the light, is a portion of the non-æther. It is a 'source' through which energy is transferred from the non-æther to the æther. By reason of its presence the æther is not a 'self-contained system' of the kind which is necessary to justify an application to it of the principle of reversal. But we can bring about this requisite state of isolation by supposing that P, after having emitted light for a definite time, say for one minute, not only ceases to emit light, but ceases to exist. This total suppression of P cuts off the communication between the æther and the non-æther, and thenceforward the æther is a self-contained system in which we may investigate the *further* progress of events by employing the principle of reversal. It will be convenient to divide time into equal intervals—say into minutes—and the definite supposition we shall make is that P emits light of wave length λ from the epoch $t=0$ till the epoch $t=$ one minute, and that at the close of this period all the contents of the sphere ρ, including P and the disturbed æther near it, are suddenly annihilated, and quiescent æther put in their place.

By the end of the first minute, when these events are supposed to take place, the undulation beyond sphere ρ has extended to a distance from f, which is about forty-seven times the distance from the earth to the moon. After those events take place, the undulation continues to advance outwards; and we may now employ upon it the principle of reversal, with the advantage of being at liberty to confine the reversal to the reversal of motions in the æther. This provides us with the means of investigating events after the first minute.

We may also include the events of the first minute by introducing two reversals; since by this contrivance we can succeed in reproducing under the new conditions, *i.e.*, within a self-contained æther, precisely the same undulation as existed during the first minute while P was emitting light. To this end let us imagine the undulation to continue its outward journey for any convenient period —say for two minutes after the annihilation of the contents of sphere ρ. This brings us to the epoch $t=$ three minutes. At this instant let reversal of all motions in the æther take place. The outflowing waves then retrace their steps, so that after the reversal the undulation becomes light converging towards the focus f. When the time $t=$ eight minutes arrives the undulation has not only converged upon f, but after passing that focus it has become an undulation of divergent spherical waves, each part of the undulation when passing the focus having crossed to the opposite side of f. At the instant $t=$ eight minutes let a second reversal of all motions in the æther take place. The light which, immediately before this second reversal, was diverging from f again becomes convergent, and within the period from $t=$ ten minutes to $t=$ eleven minutes each spherical wave for the second time passes the focus and becomes divergent, and each of these divergent waves now finds itself under such circumstances that so soon as it gets beyond little sphere ρ it becomes for all future time an exact

repetition of what the corresponding actual wave emitted by P in the first minute was, and what it would have continued to be if neither reversal had taken place.

Hitherto we have only dealt with the undulation as an undulation of spherical waves. Let us now go again over the same ground, and avail ourselves of its being legitimate to resolve the light into wavelets by Huygens's theorem.

In addition to little sphere ρ, let us draw round f two other spheres with radii r and R, r being some moderate length such as a metre, and R a much greater length, such as two or three metro-tens.[1] We shall find it convenient to imagine other spheres to be also described round f, viz., the series with radii M, 2M, 3M, &c., where M is the length of the journey which light describes each minute, which in the open æther is a distance of 1·8 metro-tens. Let us now make it our special aim to consider in what way the process we are going to apply *will resolve the part of the undulation of spherical waves which lies within sphere* r.

As before, let P for the first minute emit light of wave length λ. This light consists of the spherical waves which travel outwards through the space beyond sphere ρ. At the close of the first minute the foremost wave has reached sphere M. Throughout almost the whole of this minute a portion of the undulation has been within sphere r, which (if r is a metre) is large enough to include from 13 to 25 hundred thousand (according to the colour) of the expanding light waves.

At the end of the minute P and the rest of the contents of sphere ρ are to be annihilated, and quiescent æther is to be substituted for them within that little sphere.

Two minutes latter, *i.e.*, when $t = 3$ minutes, the immense undulation of spherical waves has got beyond the great sphere R, and has advanced into the spherical shell between spheres 2M and 3M, leaving quiescent æther behind it.

At this instant—*i.e.*, when $t = 3$ minutes—the first reversal is to take place, whereupon the waves that have been hitherto outward bound become inflowing.

Let them pursue their new course after this first reversal until the time $t = 8$ minutes. By that time the undulation has converged upon the focus, has passed it, and has again become divergent light, each part of the undulation having crossed to the opposite side of f. When the epoch $t = 8$ minutes arrives the undulation of spherical waves is travelling outwards, and has reached the space between spheres 2M and 3M, and sphere R lies in the quiescent space within the undulation.

At this instant—*i.e.*, when $t = 8$ minutes—let the second reversal take place. The undulation for the second time travels inwards, and on their inward journey the spherical waves come successively to coincide with sphere R. Accordingly if we divide the surface of sphere R into its elements $d\sigma_1$, $d\sigma_2$, &c., then by Huygens's theorem we may substitute undulations of hemispherical wavelets radiating inwards from the innumerable centres $d\sigma_1$, $d\sigma_2$, &c., to take the place of the further progress of the inward-bound undulation of spherical waves. As these innumerable undulations of wavelets advance, they sweep over the space occupied by sphere r, which is two metres across, and *within the limits of that space* the wavelets differ but very little from wavelets that are accurately flat and accurately uniform. In this way the converging spherical waves within sphere r succeeded by the same waves diverging after they pass the centre of the sphere, produce identically the same motion within sphere r as would develop itself if the innumerable undulations of nearly plane wavelets described above were made to sweep across it simultaneously. It can further be proved that the equation of energy is fulfilled in this resolution, and that in every respect the resolution is a true physical resolution.

The next step is an easy one. It is legitimate by an application of the method of limits to make the wavelets where they cross sphere r accurately plane wavelets

[1] A metro-ten is the tenth of the metros or decimal multiples of the metre. In other words, it is 10^{10} metres.

and accurately uniform, and at the same time to increase the size of sphere r to any desired extent. When this has been done we obtain the following important theorem:—

THEOREM I.

The undulation of spherical waves emitted by a luminous punctum P situated at a point f of a transparent isotropic medium, together with that preceding system of waves converging upon f, which would have been followed by this same radiation from f if P had been absent—*i.e.*, the complete undulation of spherical waves which embraces an entire past history as well as the entire future history of the undulation—can be completely resolved into undulations of plane wavelets, each wavelet being of unlimited extent in its own plane, and uniform throughout that extent. And this resolution is a true physical resolution and not merely kinematical.

An adequate conception of these plane-wavelet components can perhaps be best acquired by making temporary use of the hypothesis that the light emitted by P consists of rays, of the kind with which we are familiar when the useful hypothesis that light consists of rays is made the basis of the science of geometrical optics. Here, however, we are to obliterate these hypothetical rays and to substitute for each hypothetical ray a real undulation of plane wavelets, each wavelet having its wave-front perpendicular to the ray, and being of unlimited extent in the plane of the wavelet as well as uniform throughout that extent. To complete the picture the intensity of each undulation (*i.e.*, the square of the transversal of each of its wavelets) is to be proportional to the intensity which we have to attribute to the corresponding hypothetical ray of geometrical optics. As the number of rays is unlimited, so is the number of the undulations of plane wavelets that take their place.

The investigation requires one other fundamental thereom, of which, as it is a well-known theorem, we need only give the enunciation, premising that the direction in which an undulation of plane waves travels is in an isotropic medium perpendicular to the wave fronts.

THEOREM II.

Any number of undulations of uniform plane waves, of wave length λ, advancing in the same direction in an isotropic medium, may be united into a single resultant undulation of uniform plane waves travelling in that direction. (If the undulations to be combined are variously polarised, the resultant undulation will in general be elliptically polarised.)

From these fundamental theorems several useful inferences may be drawn; such as—

THEOREM III.

The whole of the light of wave length λ emitted by any visible object, whether self-luminous or requiring incident light to render it visible, may be resolved into undulations of uniform plane wavelets, of which there need be only one such undulation provided for each direction towards which light is propagated from the visible object.

This is an immediate corollary from Theorems I. and II.

THEOREM IV.

The light of wave length λ traversing any portion of space may be resolved into undulations of uniform plane wavelets sweeping over that space, of which there needs only one such undulation in each direction.

This also is a corollary upon Theorems I. and II.

Theorem V.

The light of wave length λ which reaches the image of an object formed by an optical instrument may be resolved into undulations of uniform plane wavelets, of which only one undulation need be provided for each of the directions along which light reaches the image.

This theorem is a particular case of Theorem IV.

Light may be resolved into wavelets in innumerable ways. Amongst these the analysis into undulations of uniform plane wavelets possesses the unique advantage that *as each undulation advances through space neither it nor any of its parts undergoes change.* Hence

Theorem VI.

To estimate the effect produced within a closed space or by the light that has reached a given image, it will suffice to draw cylinders enveloping this space or image, in all the directions from which light comes to it, and to confine our attention to the portion of each undulation of uniform plane wavelets which lies within that one of the cylinders which is perpendicular to its wave fronts.

From this group of theorems others of much interest follow; but to describe the method by which they are derived would necessitate entering upon new ground, and would unduly prolong the present abstract. It must therefore suffice to say that by some of these further propositions a beam or pencil of light is resolved into its plane-wavelet components, each of indefinite extent laterally; and that this resolution renders possible a study of the phenomena of diffraction gratings when the portions of light that reach the individual reflecting strips come from independent sources.

Some of the Results Obtained.

These theorems have made it possible to investigate the distribution of the light which is thrown off by visible objects, and they explain the experimental effects seen by Professor Abbe when light was incident upon microscopical objects under various limitations as to direction. In the course of the inquiry the total light incident on an object, or else the total light which emerges from it, has to be resolved into its plane-wavelet components; and it appears on applying this method of analysis, either to the incident or to the emergent light, that the portions of light thrown off by different parts of the object are capable of interfering, whether those portions of light had reached the object from the same or from independent sources.

Verification by Experiment.

After confirming these results by a repetition of Abbe's observations and by a large range of other experiments with the microscope, it appeared to the writer to be desirable to contrive a test experiment which could be carried out with more precision than is possible when employing the microscope.

A ruling of parallel equidistant lines seems from the theoretical point of view to be the simplest kind of visible object with detail upon it to be seen. Accordingly the object chosen for experiment was a Rowland's diffraction grating with a ruling a little more than 4½ centimetres long, and containing about 26,000 reflecting strips.

The theoretical investigation indicated that the light thrown off by the grating should be in the same directions and have the same intensities, whether the incident light which has reached the several reflecting strips have come from the same or from different sources, provided that, if they come from different sources, equal intensity of light has reached the several strips.

To test this Miss E. A. Stoney proposed to bring light from independent sources to the various parts of the grating by throwing an image of the sun upon it;

and the experiment which resulted has most satisfactorily confirmed the prediction of theory.

The light from the sun was reflected from a heliostat furnished with a 4-inch optically flat mirror, worked by Sir Howard Grubb, F.R.S. The mirror is silvered on the front, and may be relied on to furnish reflected light capable of forming a good image. The reflected beam was received by a horizontal telescope furnished with a 2-inch objective by Cook and an eyepiece by Watson. By this apparatus an image of the sun was formed in a vertical plane at a distance of a little more than a metre from the telescope, and of a size somewhat larger than the Rowland grating. Whenever there happened to be minute spots on the sun at the time of observation, the image was good enough to show them satisfactorily.

The surface of the grating was made to coincide with this image, so that the light reaching different parts of the grating came from different parts of the sun. At the same time, in consequence of the arrangements described above, all light reached the grating from nearly[1] the same direction, viz., from the direction in which the eye-stop of the telescope was seen from the grating.

When the apparatus was set up in this way, the same full series of bright impure spectra were produced as are seen when the portions of light reaching the several reflecting strips come from identical sources.

Still further to test the predicted result, a spectroscope slit was placed near the telescope, in the position of the eye-stop of the telescope. This reduced the light forming the image of the sun and impaired its definition, but still left the image good enough to ensure that the light reaching reflecting strips of the grating which are somewhat distant from one another came from different parts of the sun. The spectrum of the second order on one side was then viewed through the telescope of the spectrometer, when the Fraunhofer lines were well seen in large numbers. The E group in the green was carefully examined, and the definition was so good that all but one[2] of the 30 lines in Rowland's great map were seen. The closest doubles that were observed to be resolved were at 5265·8 in the E group, and the corona line with the iron line adjoining it at 5316·9. The spacing of these doubles is about $\frac{1}{3}$ of an Ångstrom unit, which in that part of the spectrum would, according to Lord Rayleigh's formula ($\lambda/\delta\lambda = 2n$), require a grating of 16,000 lines to resolve them in the second spectrum if the grating and the adjustments were perfect.

The performance as seen was regarded as good, considering the impossibility in some respects, and the difficulty in others, of getting the adjustments more than approximately made: 16,000 lines occupy 28 mm. on the grating, which is more than an inch. It therefore extended over a considerable part of the image of the sun which illuminated the grating. Moreover, having regard to the fact that the brightness of the light reaching the different reflecting strips was not quite the same, and to the other shortcomings mentioned above, it seems not unlikely that the whole of the 26,000 reflecting strips of the grating were actually in operation to produce such definition as was observed. If so, light was made use of from parts of the image of the sun as far asunder as $1\frac{3}{4}$ inch.

[*Note added October* 1901.—The experiment is very much improved by introducing a collimating lens between the slit and the grating. The lens employed is a lens of 73 cm. focus, and was set up at a distance of about 12 cm. in front of the grating. It does not sensibly impair the image of the sun formed on the grating, and it enables the adjustments to be *fully* made which had to be left imperfect before. When the adjustments were carefully made the spectrum of the sun in the second spectrum did not appreciably fall short in either definition,

[1] The light reaches all parts of the grating from exactly, and not only nearly, the same directions when the collimating lens described in *Note* above is added to the apparatus.

[2] The line not seen is the faint chromium line of wave length 5275·34 and of intensity 00 on Rowland's scale. It is between two stronger lines, the nearer of which is of intensity 1 and at a distance of about a fifteenth of an Ångstrom unit. This is too close for resolution by a grating of 26,000 lines in its second spectrum. The pair are, however, widely separated by the grating that was used in its fifth spectrum.

resolving power, or purity of the best spectrum that can be obtained when the spectrometer is employed in its usual way, *i.e.*, with the image of the sun thrown on the slit. No doubt, the light being now derived from a large extent of the sun's disc, sharp lines must have been fringed with faint and narrow wings owing to the rotation of the sun; but the wings were too faint and too narrow to be visible in the second spectrum.]

On the whole, the verification of the effect predicted by the new analysis appears to be satisfactory.

A modification of the experiment can be made in the absence of sunshine by throwing the image of a flat sodium flame upon the grating, when the D lines will be seen beautifully defined, and may be reversed if suitable arrangements are made in the flame. But a sodium flame cannot be made truly flat or truly steady so as to furnish an image the purity of which may be relied on like that of the sun. The solar arrangement for making the experiment is therefore to be preferred when sunshine and sufficiently good apparatus are available.

8. *A Long Period Solar Variation.*[1] *By* WILLIAM J. S. LOCKYER.

This paper consists of a discussion of the observations of the measurement of sunspot areas made since the year 1833, this year being the epoch when Schwabe commenced his series of sunspot observations on a systematic basis. The actual dates of the epochs of maxima and minima of sunspot area used in this investigation were those given by Dr. Wolf and Dr. Wolfer. As a check on the work the important results of Mr. William Ellis' discussion of the Greenwich Observations of the Magnetic Elements were utilised, as he has shown that the curves representing the magnetic elements are in almost exact accord with that representing the solar spotted area.

In dealing with the sunspot curve the first result of the investigation was to indicate that the intervals between a minimum and a *following* maximum varied regularly, the length of this period of variation amounting to a little more than three eleven-year periods, or about thirty-five years. The magnetic curves examined in the same way indicated precisely a similar variation.

An inquiry into the amount of spotted area included in each interval between consecutive sunspot minima indicated also a regular variation, the period being similar to that mentioned above—namely, about thirty-five years.

Further, it was found that the interval in time between consecutive minima was not constant but varied, as far as could be judged, regularly, the length of the period increasing and decreasing in *alternate* eleven-year periods from a mean value.

The paper then indicated that as the sun may be considered as a 'variable' star, it may be likened to the well-known variable η Aquilæ, the light of which changes rather similarly—*i.e.*, the interval between a minimum and a following maximum has a short-period variability, and the period from minimum to minimum alters.

In conclusion the author referred to the important work of Professor Ed. Brückner, who had indicated that the changes of climate were periodical, and that the mean length of the period was about thirty-five years; to Mr. Charles Egeson's investigations on territorial meteorology for South Australia; and to Professor Ed. Richter's results on his researches on the movements of glaciers.

All these investigations indicated clearly a periodical change in the meteorology of the earth's atmosphere, which were the result of this thirty-five yearly solar period, as shown by the correspondence of the respective epochs.

The paper then indicated that the next '*great*' maximum of sunspots, similar to that of 1870 and 1835, should occur at the approaching maximum, and it would be interesting to see whether all the solar, meteorological, and magnetic phenomena of those two periods were repeated.

[1] See *Proc. Royal Soc.* vol. lxviii. p. 285.

The conclusions drawn from the whole investigation were as follows:—

1. There is an *alternate* increase and decrease in the length of a sunspot period, reckoning from minimum to minimum.

2. The epoch of maximum varies *regularly* with respect to the preceding minimum.

The amplitude of this variation about the mean position is about ± 0·8 year.

The cycle of this variation is about thirty-five years.

3. The total spotted area included between any two consecutive minima varies regularly.

The cycle of this variation is about thirty-five years.

4. There is no indication of the fifty-five-year period as suggested by Dr. Wolf.

5. The climate variations indicated by Professor Brückner are generally in accordance with the thirty-five-year period.

6. The frequency of auroræ and magnetic storms shows indications of a secular period of thirty-five years.

DEPARTMENT II.—METEOROLOGY.

The following Report and Papers were read:—

1. *Report on Meteorological Observations on Ben Nevis.*

See Reports, p. 54.

2. *The Seismograph as a Sensitive Barometer.* *By* F. NAPIER DENISON, *Meteorological Office, Victoria, B.C.*

Since the installation of a 'Milne' Seismograph in connection with the Meteorological Office at Victoria, B.C., in September 1898, the author has taken up the study of the various movements of the horizontal pendulum apart from those caused by earthquakes.

In order to make a thorough investigation of this phenomenon, the author has taken the photographic records from this instrument for the years 1899 and 1900, amounting to over 3,000 feet of paper, and with a millimetre and time scale has measured the amounts and times of occurrence of all changes, including the diurnal and longer period deflections. These observations have been entered in a specially designed register, and as these observations are often of sufficient amplitude to necessitate the resetting of the boom by altering the levelling adjustment, it has been necessary to correct the above readings in order that the true and continuous movement be obtained during these years.

By studying these corrected observations in conjunction with the Victoria Synoptic Weather Charts, the author became convinced that most of these movements were due to meteorological causes. In order therefore to be able to pursue this study further, he has plotted these observations upon ·1 inch squared paper: the time scale used was 2·4 inches per day, and ·1 inch to equal one millimetre. Above this curve for each month was plotted the Victoria barometer from the tri-daily observations, and surmounting this was entered the tri-daily record of the direction and velocity of the winds and precipitation.

The results from the plottings for the year 1899 when studied in conjunction with the corresponding weather charts proved so interesting that a brief paper upon this subject was read before the last meeting of the Royal Meteorological Society. Since then the author has completed the plottings for 1900, and, in order to increase their value, has added the Victoria tidal curve also.

The following notes have been deduced from these observations:—

(1) The crust of the earth is depressed under areas of high barometric pressure, and elevated under areas of low pressure.

(2) When the barometer is high over the Pacific slope from British Columbia to California and low over the adjacent ocean, the horizontal pendulum is deflected towards the east.

(3) When the barometer is high off the coast and low over the Pacific slope, the horizontal pendulum is deflected towards the west.

(4) The horizontal pendulum tends to move east during the winter months and west throughout the summer.

(5) The total westerly movement (signifying a depression of the coast) exceeds the easterly swing for the year 1899 by 54·9 millimetres and by 20·7 for 1900.

(6) When an extensive ocean storm area is approaching the coast of Vancouver Island, while the barometer is high over the Pacific slope, the pendulum will steadily travel eastward before the coast barometers begin to fall, or its presence is noticeable upon the synoptic weather chart.

(7) Should such a storm be followed by an extensive high pressure area, the pendulum will turn and move steadily toward the westward, some time before the local barometer begins to rise and before the winds have shifted to the westward.

(8) Should an important storm area move down the coast from Alaska and be followed by an extensive one of high pressure and a cold wave extending from the Yukon south-eastward, the pendulum swings to the westward, usually before the storm has reached this latitude. These are termed abnormal winter movements, and cause the few cold days experienced in this vicinity.

(9) The greatest monthly range occurs during the stormy winter months, and the smallest range takes place during the summer type of almost continuous fine weather.

(10) The diurnal range is most pronounced during the summer months, when the greatest amount of sunshine is recorded, and the least amount of rain.

(11) Fine weather is usually preceded by a westerly movement of the pendulum, due to an approaching ocean high area which spreads inland over the province, while further south the barometer is comparatively low.

(12) A careful perusal of the two years' plottings proves that during the normal type of summer and winter barometric distribution the barometer and pendulum curves tend to come together as areas of low pressure approach the coast, and diverge when high areas follow the same course.

The above brief and incomplete summary of deductions derived from these two years' observations is respectfully submitted with a strong desire that this investigation be taken up by a special committee, and if this study of the pendulum's warnings tends to aid the forecasting of ocean storms upon this distant seaboard of the empire, may not a similar study at home lead to the adoption of simple seismographs throughout the kingdom to be used as sensitive barometers, as an aid in warning the advent of the great Atlantic storms before they reach the western coast?

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3. *On Meteorological Phenomena in Relation to Changes in the Vertical. By* Professor J. Milne, *F.R.S.*

WEDNESDAY, SEPTEMBER 18.

The following Report and Papers were read:—

1. *Report on the Determination of Magnetic Force on Board Ship.*

See Reports, p. 29.

2. *On a New Form of Instrument for Observing the Magnetic Dip and Intensity on Board Ship at Sea. By* Captain E. W. Creak, *C.B., F.R.S.* See Reports, p. 29.

3. *Note on some Results obtained with the Self-recording Instruments for the Antarctic Expedition. By* Dr. R. T. Glazebrook, *F.R.S.*

4. *On a Determination by a Thermal Method of the Variation of the Critical Velocity of Water with Temperature. By* H. T. Barnes, *M.A.Sc., D.Sc., Lecturer in Physics, and* E. G. Coker, *M.A., D.Sc., Assistant Professor of Civil Engineering, McGill University, Montreal.*

The critical velocity, or point at which the flow of water through a pipe changes from stream-line to eddy motion, has been the subject of a series of experiments by Osborne Reynolds from the philosophical as well as the practical aspect. Two methods, which are too well known to require description, were adopted in his experiments—the method of colour bands and the determination of the law of resistance governing the flow at velocities above and below the critical velocity. From the results of his work Reynolds was able to verify certain mathematical deductions as to the effect of viscosity and diameter, which led to exceedingly simple expressions for determining the change in the flow. The effect of temperature was, however, less completely verified. In so far as the critical velocity is dependent on the viscosity, the temperature coefficient of the viscosity was taken as representing this temperature change. General experimental results indicated, at least approximately, that the law of Poiseuille for the flow through capillary tubes held for the critical velocity between 4° and 22° C. It was deemed desirable by the authors, on account of the large effect produced by temperature, to determine this coefficient directly by a new method, and more especially as the law of Poiseuille itself was deduced from experiments ranging only as high as 45° C.

In the present paper a new thermal method of measurement is described, and also experiments by this method with a brass pipe 0·414 inch in diameter at different temperatures between 15° and 86° C., together with the general results so far as it is yet possible to communicate them, showing the reformation under perfectly steady and uniform conditions of the stream-line flow at velocities very much above the critical point measured by Reynolds.

Thermal Method of Measuring Critical Velocity.

If water be heated while flowing through tubes in stream-line motion, the distribution of heat throughout the water column is not uniform. In the case where the heat is applied at the outside of the tube, as in the experiments of L. Graetz, only the few layers which are almost stationary in direct contact with the tube will be heated, while the inflow water, which passes directly through the central portion at a much greater velocity, will remain almost entirely unheated. In the case where the heat is received from a central wire, the heat is carried off by the quickly moving water in a cloak as it were around the wire, leaving the sides of the tube unheated. At and beyond the point where eddies make their appearance in the flow, the entire column of water is mixed and stirred, and the temperature distribution becomes uniform. The point of change, or the critical velocity, may be then very clearly defined by observing the sudden increase in the temperature of the flowing water. In some of the first experiments this change of temperature was observed by noting the increase in resistance of a platinum wire threaded through the centre of the tube heated on the outside, and the preliminary results showed that the presence of a wire of 6 mils' thickness in a tube of about ¼ inch

in diameter had apparently no measurable influence in causing an earlier breaking up of the stream-line flow. Although the electrothermal method of measurement was quite satisfactory, it was found that the point of change was determined more simply by placing the bulb of a sensitive mercury thermometer in the path of the water as it emerged from the tube, and this had also the additional advantage of showing the true temperature of the water. A glass prolongation, of slightly greater diameter and connected carefully to the brass pipe by a specially constructed cone or adapter, enabled the reading of the thermometer to be observed. It was a matter of considerable surprise to the authors to see the very sudden way in which the reading of the thermometer indicated the point of change in the character of the flow by an almost instantaneous change of reading. That the change in the reading indicates the critical point was shown by introducing a colour band in the ordinary way, in which case the band disappeared at the same moment the jump in the thermometer thread took place.

Since in the experiments the tube was heated on the outside, it might at first sight appear that the temperature difference between the layers of water in direct contact and the central column might produce a disturbing action on the flow, but as this temperature difference was always small, the total jump in the thermometer being seldom over a few tenths of a degree, the disturbance, if any, was reduced to a minimum. Moreover, special experiments were repeatedly made to determine a possible disturbing effect by maintaining the temperature of the walls of the tube at different points above and below the water in the tube, but none could be detected.

It was necessary to have only a few degrees difference in temperature between the walls of the tube and inflow water to obtain a measurable reading.

Description of the Apparatus.

We were fortunate in having at our disposal, through the kindness of Dean Bovey, the facilities afforded by the hydraulic laboratory, where the large experimental tank, 20 feet high and 25 square feet in area, served admirably for a reservoir. The tank stood on the bed rock, and was therefore free from vibration or disturbance, and after the eddies had died out, occasioned by filling, the water was in as completely quiet a state as possible. The water used for the experiments was supplied from the Montreal mains, and was quite clear. It would not have been possible to use distilled water owing to the large quantity required, but every precaution was taken in the way of repeated cleaning to have the water pure.

The rest of the apparatus was designed, and for the most part constructed, in the laboratory, and served admirably for fulfilling the required conditions for carrying out the experiments. Subsequently it was found that by a few simple alterations the method of colour bands could be used as well for the experiments with the large pipes.

Each of the metal pipes studied was fitted with a metal trumpet flare to direct the flow as it entered, the point of junction being very carefully smoothed so as to produce no disturbing action. The walls of these pipes were maintained at a constant temperature, above or below the temperature of the water flowing through, by means of a jacket, through which water was circulated by a centrifugal pump. A graduated valve regulated the flow, which was caught and measured in an accurately calibrated copper measure.

Experimental Results.

Two tables are given, the first showing the effect produced by increasing the head of water in slightly increasing the critical velocity; and the second, the effect of temperature between 15° and 86° C. These experiments were made with the 0·414-inch brass pipe.

Two other tables are given, one showing the agreement of the observations of Reynolds by the method of colour bands with those of the authors, when reduced

to a size of pipe equal to theirs, and the other showing that the observations of Reynolds between 4° and 22° C. give a closer agreement with the authors' temperature formula than with the formula of Poiseuille.

The law showing the dependence of the critical velocity on the temperature obtained by the authors may be stated thus:—

$$P = f(T) = (1 + \cdot 0300T + \cdot 000704^{2}T)^{-1}$$

between 15° and 86° C.; while the law of Poiseuille reads:—

$$(1 + \cdot 03368T + \cdot 00221T^{2})^{-1}$$

between 0° and 45° C.

Experiments on Stream-line Flow at High Velocities.

It was found further that the unusually steady conditions obtained in the large tank conduced to some interesting results in regard to stream-line flow at high velocities. For certain sizes of pipes, over half an inch to as large as the authors have yet used, *i.e.*, $2\frac{1}{4}$ inches, the flow re-formed again to stream-line above the critical point of Reynolds, and persisted apparently as the stable flow to velocities ranging from 12 to 20 feet per second. Beyond these velocities they were unable to go, but in some instances no sign of breaking down occurred at these points.

Two experiments were tried, which illustrate clearly that water flowing with a perfectly smooth, unruffled surface is in stream-line motion. A circular orifice was inserted in the side of the tank, which gave a clear rod-like jet of water that issued horizontally under a high head and curved in a parabolic arc under gravity. After all initial disturbances had died out in the tank a colour band was introduced by bringing the colour tube to within about 3 inches of the centre of the orifice. A clearly defined and sharp line of colour threaded its way through the jet of water, shifting slowly from centre to side and back to centre again, affected probably by slight movements in the tank. This thread of colour was distinctly visible down to the point where the jet of water impinged against the waste weir, a distance of 15 feet. By introducing an excess of colour a similar phenomenon to the breaking down of the stream-line flow in a tube was noted, and the jet became suffused with colour, broken, and unsteady up to within a foot or two of the orifice. On reducing the quantity of colour the stream-lines re-formed and the water became smooth, clear, and steady, threaded by the sharp line of colour as before. Two sharp-edged orifices were tried, $\frac{3}{4}$ and $2\frac{1}{4}$ inches diameter respectively, with coefficients of discharge equal to 0·970. With the heads used the highest velocity reached by the outflowing water, calculated in the usual way from the formula

$$V = 0{\cdot}970\sqrt{2gh}$$

was 30 feet per second.

5. *The Interference and Polarisation of Electric Waves. By* Professor G. QUINCKE.—See Reports, p. 39.

6. *On the Effects of Magnetisation on the Electrical Conductivity of Iron and Nickel. By* GUY BARLOW, *B.Sc.*

The object of the experiments was to determine whether any simple relation exists between the change of electrical resistance and the intensity of magnetisation in iron and nickel wire when magnetised longitudinally. The effects of hysteresis as shown by the magnetic change of resistance were also examined.

The Wheatstone Bridge method was employed, with a bridge wire of low resistance. The experimental wire was wound longitudinally on a thin rod of

wood, the 'comparison' coil being of copper, and wound close to it on the same bobbin. These coils were enclosed in a glass tube and placed within the magnetising coil which was provided with a water-jacket.

Auxiliary coils of German silver were connected in the other two arms of the bridge so as to increase the sensibility of the arrangement. The magnetisation was determined by the ballistic method. Wires of iron, steel, and nickel were examined. The curves of 'ascending reversals' were obtained for the change of resistance and for the magnetisation. A comparison of these curves shows the manner in which the change of resistance depends on the magnetisation. The results obtained by this method showed that the change of resistance is not proportional to any single power of the magnetisation, but can be represented by a function of the type $aI^2 + bI^4 + cI^6$.

Hysteresis loops were also obtained showing the effect of cyclic variations of field on the change of resistance and on the magnetisation in the same specimens. These curves show that the change of resistance vanishes in the cycle when the magnetisation vanishes, but the change of resistance shows considerable hysteresis with regard to the magnetisation.

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7. *The Influence of a Magnetic Field on the Viscosity of Magnetisable Liquids. By* Professor A. GRAY, *F.R.S.*

8. *The Influence of a Magnetic Field on the Viscosity of Magnetisable Solids. By* Professor A. GRAY, *F.R.S.*

9. *Magnetisation of Electrolytic Nickel. By* JAMES W. PECK *and* ROBERT A. HOUSTOUN.

An account is given of experiments in progress to determine the magnetic quality of electrolytically deposited nickel. The method of deposition is described, and the difficulty of getting adherent deposits of sufficient thickness is pointed out. Magnetic measurements (by the ballistic step-by-step method) made upon the nickel are given, and for purposes of comparison similar measurements for specially pure nickel wires are made. These wires contained only from 0·25 per cent. to 0·42 per cent. of impurity (chiefly iron). Values for H, I, B, k, μ are given; and hysteresis cycles and permeability curves are drawn out. A moving coil galvanometer (as recommended by Ewing) is used for many of the ballistic measurements, and is found to be very convenient.

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10. *A New Form of Permeameter. By* Professor F. G. BAILY, *M.A.*

The apparatus depends on the measurement of the ratio of B to H in the sample. A complete magnetic circuit is formed by two lengths of the sample joined by short iron blocks at the ends. Magnetising coils are placed round the sample. In one of the blocks is a narrow gap perpendicular to the direction of the lines of force. Above this is pivoted a pair of astatic magnets. The lower magnet is influenced by the difference of magnetic potential between the two sides of the gap, the force being proportional to B. Round the upper magnet is placed a small coil in series with the main magnetising coils, which acts on the magnet with a force proportional to H. Using the principle of the sine galvanometer, the coil is rotated until the two forces are balanced, the position of the magnet system being along the line of the gap. Then $\mu = \frac{B}{H} = f(\theta)$. The coil is shaped to give an almost uniform scale through some 80° of arc, and the permeability is read directly on the scale.

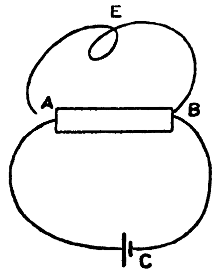
The scale is calibrated for a standard size of specimen, and the value for any other size is obtained by multiplying by the ratio. A wide range is obtained by using only a part of the magnetising coils when the permeability is high.

The magnetising force is read on a separate instrument, such as a suitable amperemeter. Regulating resistances, a reversing switch for demagnetising, and a switch for altering the range are added.

11. *Note on the Coherer.* *By* Professor JAMES BLYTH, *M.A., LL.D.*

The object of this note is to draw attention to some experimental results connected with the ordinary filings-coherer, which I can hardly think are new, but which I have not seen specially noticed.

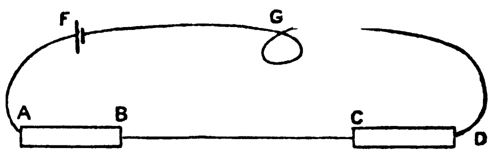
When a coherer is placed in circuit with a battery, and when no current passes through it, it is obvious that its terminals must correspond to the charged plates of a condenser, and that the P.D. between them must be equal to the E.M.F. of the battery. Let AB be the coherer and C the battery, then the P.D. between A and B is equal to the E.M.F. of C. If now A and B be connected for an instant by a circuit containing a coil E having self-induction, the coherer AB will be found to have assumed the conducting instead of the insulating condition. This can be tested by switching a galvanometer into the battery circuit and observing the deflection. If, however, the coherer AB be short-circuited for an instant by a coil having the same resistance as E, but wound so as to have no self-induction, the coherer does not become a conductor.



This would seem to show that the discharge of the condenser-coherer must be of a distinctly oscillatory nature before the well-known effect of coherence is produced.

The next result I have to refer to depends essentially on the same cause.

Let two coherers AB and CD be included in the same circuit with a battery F and a galvanometer or bell G. Also let a Voss machine be placed near AB so as to produce an oscillatory spark near AB, but let CD be placed so far away as to be beyond the direct action of the spark; then in general it will be found that when AB becomes a conductor suddenly the jerk given to CD is sufficient to make it also a conductor, and the galvanometer will deflect or the bell ring. If CD be now tapped, the bell stops, although AB has been left untouched. This shows that if one coherer in a circuit suddenly assumes the conducting condition all other coherers in the same circuit tend to do the same.



Section B.—CHEMISTRY.

PRESIDENT OF THE SECTION—Professor PERCY F. FRANKLAND, Ph.D., F.R.S.

THURSDAY, SEPTEMBER 12.

The President delivered the following Address:—

The Position of British Chemistry at the Dawn of the Twentieth Century.

Two circumstances unite in rendering this year especially appropriate for the survey and valuation of all departments of British life and organisation—the dawn of a new century, the close of the Victorian era. It is a moment when not only the nation as a whole, but every group of persons drawn together by whatever bond, and indeed each individual for himself, must involuntarily ask the question, Are we progressing or receding, or are we standing still? Upon us, then, who are bound together by the common interest which we have in that science to which this Section is devoted there forces itself the question, What is the position of British Chemistry at the present moment, how does this present bear comparison with the past, and what are the prospects for the future?

To bring before you some considerations with respect to the answer which should be given to this question, or rather series of questions, will be my endeavour in responding to the honour which has been conferred on me of inaugurating the work of our Section at this Meeting of the Association.

It is with no light heart that I undertake this task, for there are present here to-day those whose much longer experience and far more intimate connection with the progress of our science render it presumption on my part to address them on this subject at all.

It is well known that the history of British Chemistry, as indeed that of British Science in general, is a very remarkable one: it is almost entirely made up of achievements which are the result of private initiative; and the persons who have taken part in the making of this history have, with some notable exceptions, not been servants of the State, and have thus differed from the makers of scientific history in almost every other country in the world. Thus the opportunities for the investigations which are recorded in the 'Transactions' of our Chemical Society have, for the most part, not been provided out of the public purse, but by private individuals or by institutions which have been created by private benefaction.

This unique condition of things is well illustrated by taking up a volume of the 'Chemical Society's Journal' and glancing at the table of contents.

Thus in the volume for 1881, taken at random, we find that, out of the seventy-five original communications which it contains, only thirteen emanate from Government laboratories, whilst what will surely not a little surprise the scientific historian of some centuries hence is the circumstance that there are only four communications from the so-called 'ancient seats of learning' of the United Kingdom, no fewer than three of which are by one and the same investigator.

Again, most noteworthy is the fact that as many as five contributions are from distinguished amateurs. We have been told, on what many persons regard as high authority, that England is suffering from amateurism in all departments of life; and however true this may be as a general proposition, the amateurs of British Science, like Gladstone, Schunck, and Perkin amongst living chemists, are assuredly some of the most valued possessions of this country.

On looking back a quarter of a century into the past it is at once apparent how greatly during that short period of time—less than a generation of men—have the opportunities for higher chemical training been extended and multiplied in our midst. I think I shall not be far wrong in saying that until twenty-five years ago practically the only public laboratories in which the higher study of chemistry could be pursued were those of the Royal College of Chemistry, the Royal Institution, of University and King's Colleges, London, the University laboratories of England, Scotland, and Ireland, as well as those of the Queen's Colleges and of the Royal College of Science in the sister island: to which must be added the laboratories of two institutions of a somewhat different type, viz., Owens College, Manchester, and Anderson's College, in this great city of the north. It is the rapid multiplication of institutions of the Owens College type that constitutes probably the most important feature in the higher intellectual development of the population of this country during the past quarter of a century; indeed, it may very possibly be found in the future that this constitutes the most striking landmark in the history of British intellectual progress during recent times. A glance at the following table will show the remarkably rapid growth of these institutions during the last quarter of the nineteenth century:—

Opening of University Colleges.

University College, London .	1828	University College, Nottingham	1877
King's College, London .	1831	Firth College, Sheffield .	1879
Owens College, Manchester .	1851	Mason College, Birmingham	1880
Durham College of Science, Newcastle	1871	University College, Liverpool	1882
University College, Aberystwith	1872	University College, Dundee .	1882
Yorkshire College, Leeds .	1875	University College, Cardiff .	1883
University College, Bristol .	1876	University College, Bangor .	1884

Finsbury Technical College	City Guilds . . .	1883
Central Institution		1885

Thus the opening of the greater number of these institutions falls within the decade 1875–1884.

The benefits arising from the creation of these numerous institutions have not, however, been by any means limited to those persons who have actually taken advantage of their instruction, for their existence has stimulated the establishment of many other institutions, some of which, like the two Colleges founded and maintained out of the resources of the City and Guilds of London, although more limited in their scope, afford equal or even greater opportunities for higher scientific training in the particular branches which are represented.

The foundation of these University Colleges and of other institutions for higher education by private initiative, and without a particle of assistance from the public exchequer, is quite in keeping with the history of a country in which it is recognised that the Government does not lead, but only follows where it is drawn or propelled.

It would certainly be anticipated that such a large addition to the machinery for higher scientific training as is represented by the creation of these numerous local colleges during the past twenty-five years would have had a marked influence on the output of scientific discovery in this country. We will endeavour to ascertain whether such a result is discernible in the case of chemical science. Turning to the 'Transactions of the Chemical Society,' I have compiled the following table in the hope of obtaining some information on this point;

Original Communications in the Transactions of the Chemical Society.

1849	29	1862	81	1875	49	1888	75
1850	33	1863	51	1876	54	1889	71
1851	33	1864	54	1877	58	1890	71
1852	28	1865	49	1878	61	1891	95
1853	22	1866	47	1879	84	1892	90
1854	23	1867	49	1880	75	1893	104
1855	30	1868	47	1881	75	1894	83
1856	14	1869	37	1882	65	1895	116
1857	14	1870	38	1883	63	1896	117
1858	30	1871	28	1884	57	1897	114
1859	21	1872	32	1885	85	1898	102
1860	25	1873	46	1886	85	1899	120
1861	32	1874	49	1887	88	1900	127

The information furnished by these figures is also presented in a graphic form by means of the lower curve in the diagram facing p. 593.

The activity displayed in chemical research, as measured by the number of original communications to the Chemical Society, is, however, best followed by a consideration of the aggregate number of papers contributed during the three following decades:—

Decade	Total Number of Papers in 'Transactions of Chemical Society'
1855–1864	352
1865–1874	422
1875–1884	641
1885–1894	847

From these figures it is manifest, even without the application of any of those mathematical processes in which modern chemists are becoming so expert, that the most remarkable increase in the number of original investigations is indeed coincident with that decade, 1875–1884, in which the great majority of the institutions to which I have referred began to throw their prismatic rays of knowledge on many thousands who until then were sitting in shadow or even in darkness.

That these new institutions should have so immediately borne fruit in the manner I have indicated cannot fail to be surprising to those who have been associated with the early years of almost any of these colleges, for when a faithful record of the experiences of their first professors is written the extraordinary obstacles which these pioneers had to encounter, and which in so many cases they successfully overcame, should afford material for a most remarkable, instructive, and even amusing volume. The worthy founders and their executors or trustees appear in general to have supposed that it was only necessary to provide a spacious building, and then appoint a staff of professors who were to do the rest, whilst the necessity of funds for annual upkeep, for libraries, and for assistants was almost overlooked.

It has indeed been learnt by bitter experience that the cost of efficiently maintaining institutions of this most ambitious character is enormously greater than was supposed in this country twenty-five years ago, and that founding a college, far from resembling the inauguration of a remunerative business, is very like entrance into the bond of matrimony, with its attendant annually increasing demand upon the pecuniary resources of the paterfamilias.

It would not indeed be surprising if some of these modern colleges had been long debarred from contributing directly to the progress of scientific investigation in this country, for this was often assuredly considered amongst the least of the many arduous duties imposed upon their first professors. Ascertained capacity to enrich science was in some cases almost a presumptive disqualification for their

chairs, or at any rate took a back seat beside enthusiasm for evening classes and faith in the efficacy of that mysterious panacea 'technical instruction.' It is indeed lamentable to think of the valuable years of productive work lost to the country through so much of the energy of these early professors having been sacrificed to these veritable fetishes of our would-be educational reformers.

Notwithstanding the unfavourable conditions under which most of these university colleges had in the first instance to carry on work, it was not long before they showed that they were to become, even during the tenure of office of their first professors, important centres for the prosecution of research—at least as far as chemical science was concerned. Owens College had indeed already led the way in this matter before the period with which I am more especially concerned to-day, for there the first professor of chemistry had pursued his memorable investigations on the organo-metallic compounds, and had, within the first five years after the foundation of the College, enunciated that generalisation which was subsequently extended into the *law of valency*; whilst under his successors, Sir Henry Roscoe, Schorlemmer, Harold Dixon, and Perkin, jun., the Owens College has become perhaps the largest and best equipped school of scientific chemistry in the British Islands.

From the Yorkshire College, Leeds, opened in 1875, there proceeded immediately in rapid succession that whole series of careful investigations relating more especially to specific volume and other physical constants which we associate with its first chemical professor, Thorpe, and his coadjutors.

In the west of England, where the University College of Bristol was opened in 1876, the chair of chemistry was first occupied by the man who has so recently once more proved to the world that there are discoveries made in these islands which for striking originality and independence are unsurpassed and hardly equalled elsewhere. It was during his tenure of the chair at Bristol that Ramsay, assisted by his able fellow-worker and successor Sidney Young, carried out those important and most laborious investigations on vapour pressure and the thermal properties of liquids which not only displayed his extraordinary fertility and resource as an experimenter, but also revealed that exceptional freshness of mind which has enabled him to discern new methods of attacking problems that have already engaged the attention of many able men before him.

Turning from the west of England to the Midlands, where, in 1880, there was founded, through the private munificence of the late Sir Josiah Mason, a college bearing his name, which, before even attaining its majority, was transformed at the psychological moment, as by the wand of the magician, into the University of Birmingham. The first professor of chemistry at the Mason College, my distinguished predecessor, Tilden, soon made opportunity there to continue those early researches on the terpenes with which his name will always be associated. We find him also further elaborating the important uses as a reagent of nitrosyl chloride, which he had a number of years previously shown how to prepare in a state of purity, and which has played a somewhat similar part in the exploration of the terpene hydrocarbons that phenylhydrazine has done in the elucidation of the sugar-group. In addition to these investigations we find Tilden at Birmingham also turning his attention to some of the phenomena attending the solution of salts. The younger men attached to the Mason College also found there the opportunity of enriching chemical science with the results of notable investigations; for do we not all remember Thomas Turner's valuable contributions to our knowledge of the influence of chemical composition on the physical and mechanical properties of cast iron? Whilst early amongst those detailed investigations on the phenomena of solution, which in recent years have had such far-reaching effects on the development of our science, must be mentioned Dr. Nicol's experiments on the volume changes attending the mixture of salt solutions, and on the molecular volume, the boiling-point, and expansion of such solutions.

In the bleak north-east of our island, at Dundee, where a college was founded in 1882 with an extremely handsome endowment by members of the Baxter family, the first professor of chemistry, Carnelley, fired by that restless and almost

perfervid energy which doubtless hastened his untimely end, soon found opportunity to interrogate Nature in various directions, notwithstanding the arduous teaching duties which his insatiable love of work had imposed upon himself. Thus, already in 1884, we find him, in his quest for material which should throw light on the periodic relationship of the elements, continuing his laborious work on melting-points and publishing those two ponderous quarto volumes in which every known melting-point was recorded, and forming truly one of the most remarkable compilations ever attempted in our science. Of these volumes he might indeed have said, 'Exegi monumentum ære perennius,' for they will assuredly prove a record of the boundless energy which characterised the man, more imperishable even than the memorial tablet erected by his admiring students and friends in the entrance hall of the Dundee laboratory, which he built and loved so well.

Yet another chemist, whose untimely death we have had to lament during the past twenty years, laboured with marked zeal in one of these new colleges, for it was at Aberystwith that Humpidge, regardless of his delicate health and in spite of the altogether unreasonable burden of teaching duties imposed upon him by the terms of his appointment, contributed to our knowledge of the atomic weight of beryllium, and participated in establishing the position occupied by that metal in the natural classification of the elements.

Time does not permit me to further dilate upon the great activity displayed by many of the first occupants of the chairs of chemistry in these provincial University Colleges. It is also unnecessary for me to do more than remind you of the work accomplished by the two Colleges of the City and Guilds of London, the chemical laboratories of which have from their very inception been under the stimulating influences of Dr. Armstrong and Professor Meldola, foci of research from which a number of young chemists of distinction have already emanated.

In recent years we have witnessed the genesis of another class of institution, less ambitious in their aspirations than the University Colleges, but indirectly also of much importance in their bearing upon the nurture of scientific chemistry in this country. I refer to the so-called Polytechnics which have sprung up in several parts of the Metropolis, and to some other institutions of similar scope in different parts of the country. If research in the University Colleges has been the product of their professors rather than of the environment which they afford, assuredly this is even far more so in the case of these Polytechnics, which are primarily evening schools for the benefit of those who have other occupations during the day. That the young lecturers on chemistry at these places should find time and opportunity for original research, and that sometimes of a very high order, is indeed a brilliant testimonial to their indomitable energy and resourcefulness. Overburdened with large classes until late hours at night, often in those remote and hideous parts of London which suggest to most of us only Slumland and the philanthropic efforts of Toynbee Hall or of Dr. Barnardo, these young chemists awake in the morning only to return as rapidly as possible to those laboratories which exercise on them a fascination as subtle and magnetic as that which draws the commonplace Englishman to the golf-links, the cricket-field, or the racecourse. It was in the laboratory of such a technical school, the Heriot Watt College, at Edinburgh, that my distinguished predecessor in this chair, my friend Professor Perkin, created his opportunities for devising and carrying out those now classical methods of building up carbon rings which are the admiration of all organic chemists throughout the world; methods which he has recently brought to such a pitch of perfection that he is not only able to forge these rings in great variety, but to 'bridge' them with links of carbon atoms. It was at the Heriot Watt College also that his work on berberin was performed, and it was here that he contracted that fertile alliance with Dr. Kipping, his able coadjutor in so many valuable investigations.

At the London Polytechnics, again, more recently, we have had similar examples of fertility, for are we not all familiar with the masterly work of Mr. W. J. Pope, who by his investigations at the Goldsmiths' Institute has extended our knowledge of asymmetric atoms, and has shown that optical activity, which hitherto had only been associated with carbon, and somewhat doubtfully with

nitrogen, can certainly be produced, not only by asymmetric pentad nitrogen, but also by tetravalent tin and sulphur? Dr. Hewitt, again, whom I am proud to number among my former students, has shown that the laboratory of the People's Palace, Whitechapel, may be made a centre in which abstruse investigations on the aromatic compounds can be carried on.

There is, however, perhaps nothing which testifies more strongly to the zeal for original investigation amongst British chemists than the manner in which some of the science masters at our schools have participated in the advancement of chemical knowledge. Some of these schools have, indeed, from time to time secured the services of men whose names are indelibly engraved on the records of scientific chemistry, and it is from the laboratories of these schools that in some cases perhaps their best work has emanated. Of the chemical investigators who have laboured in school laboratories there occur to me, amongst the living, Debus and Clowes at Queenwood, Tilden and Shenstone at Clifton, Purdie at Newcastle-under-Lyme, Brereton Baker at Dulwich, Charles Baker at Shrewsbury. To these names might be added many more; indeed an examination of the list of Fellows of the Chemical Society shows at what a number of schools throughout the country the chemical teaching is now imparted by men who have themselves advanced the science which they profess.

From the conspicuous instances which I have brought before you—and they might, did time allow, be greatly multiplied—it must be obvious that if a chemist only possesses the necessary enthusiasm and qualifications he will, no matter how inauspicious his surroundings, succeed in doing something to extend the boundaries of his science, and I think I may go further and say without fear of contradiction that in this devotion to research the chemist in this country usually throws into the shade the representatives of other branches of science. How is this pre-eminent zeal of the British chemist to be explained? I believe that there are two principal causes in operation which have brought about this result. Firstly, the great majority of the higher chemical teachers in this country have been trained in Germany, or have been trained by men who were themselves trained there; and secondly, they have only in exceptional cases been educated at the ancient seats of learning. Their inspiration and enthusiasm are almost invariably directly or indirectly traceable to a German origin, and this fire is kept alive by their remaining in constant touch with German chemical literature.

It is being continually impressed upon us in the newspapers and dinned into our ears from every platform that it is imperative for this country to approximate more to German ideas and methods, and in general to cast away our insular prejudices, obstinacy, and self-satisfaction. We chemists have already done these things; we have emancipated ourselves from the mischievous illusions which have a tendency to thrive in a country enjoying an isolated geographical position. For, during the last half century the academic springs of Germany have been visited by a stream of young English chemists, a stream which, for the perennial regularity of its flow, reminds one indeed of the pilgrimage made by our fashionable invalids to the same country in the hope of correcting the effects of high living by the waters of Homburg, Kissingen, and Wiesbaden. There must indeed be few chemists who return from the German temples of science without bringing back at least a spark of the sacred fire to be kindled on an altar at home; and although at times it may be stifled by the island fog, or burn low through the scarcity of fuel, it generally smoulders long before going out altogether.

The chemist, again, is generally, as I have said, unfettered by an English university record: he stands or falls by the work of his life, and not, as so many others do, by the reputation which they have made in three short years of adolescence at one of the ancient seats of learning.

The spirit of research, which was formerly but a sporadic manifestation within the walls of these venerable institutions, has, however, now become endemic there also, and for a number of years past chemical literature has received a continuous stream of original communications from Oxford and Cambridge, as well as from the Universities of Scotland and Ireland. Instead of those occasional contributions which were customary in the past, we have now evidence that these centres

in several cases yield to none in the energy and success with which chemical investigation is being pursued, and that the work of the chemical staff is being shared in by advanced pupils trained at these universities themselves. In this connection it is quite unnecessary for me to remind you of the contributions to British chemistry within recent years by Crum Brown and his pupils at Edinburgh, by Japp at Aberdeen, by Purdie and James Walker at the duplex university now working so harmoniously north and south of the Tay, by Emerson Reynolds at Dublin, and by Harcourt and Harold Dixon, Liveing and Dewar, Ruhemann, Heycock and Neville, Fenton, Sell, Marsh, and others, who have brought our science into such living prominence on the banks of the Cam and the Isis.

It is, however, not at home only that British chemists have displayed their devotion to research, for with the world-wide relations of the empire it has naturally fallen to the lot of some of our number to carry the science to the uttermost parts of the earth, but it is surely a matter of which we may be justly proud that some of these missionaries, like Mallett, Liversidge, Pedler and Rennie, have in these distant lands carried out a number of most important scientific investigations; whilst to one of them, Dr. Divers, belongs the great distinction, not only of having carried chemistry to the Far East, but of having reared a most active school of chemical research in that fascinating island empire of the rising sun and the chrysanthemum which has won the unfeigned admiration of the West.

The annals of British Chemistry are, however, by no means an exclusive record of the exploits of those engaged in the teaching of our science. I have already referred to the importance of the contributions made by men of leisure, but an equally noteworthy feature of British Chemistry is that its progress has been so often furthered by men who have snatched the time for investigation out of a busy professional or industrial life. Belonging to this category the names of a long line of distinguished chemists of our own time suggest themselves: Warren de la Rue, Hugo Müller, Sir John Lawes, Sir William Crookes, Sir William Abney, Peter Griess, Newlands, O'Sullivan, Horace and Adrian Brown, Harris Morris, Cross, and Bevan. To this group of chemists belongs also Dr. Ludwig Mond, whose technical researches have been of such great value to industrial chemistry, whilst his devotion to the pure science is attested by his interesting discovery and investigation of the metallic carbonyl compounds, and by his conception and munificent endowment of the Davy-Faraday Laboratory, in which such unique opportunities for research have been provided by him.

This would appear to be the most fitting moment also to refer to certain other institutions intended for purposes of research which have been established during the past twenty-five years. Of these the first is the Rothamsted Laboratory, so celebrated during the last half-century for the memorable investigations of Lawes, Gilbert, Pugh, and Warington, but which has more recently, through the generosity of the late Sir John Lawes, been rendered a permanent home for the elucidation of agricultural problems both by laboratory experiments and by trials in the field. Secondly, there is the Research Laboratory which the Pharmaceutical Society has established with the view of raising to a higher level the chemical education of its most promising future members. This laboratory has furnished the opportunity for the valuable investigations of its first director, Professor Dunstan, and of his successor, Dr. Collie. Still more recently a chemical research laboratory has been established in the Imperial Institute. That noble building has within the last few years undergone a process of transverse subdivision, one-half having assumed an independent existence as the nucleus of that still crystallising body, the University of London; whilst in the remaining half the work of the Institute is now carried on in such silence that we have almost forgotten its existence. For where is the florid music with which on summer nights the air of South Kensington was wont to reverberate? Gone. Gone also are the tea-tables, the gardens with their million fairy lights, and the promenading crowds in gay attire. But if the Institute, founded by public subscription to watch over and advance the prosperity of the British dominions, has been impoverished by the discontinuance of these revels, it has become enriched and has gained in dignity by the creation within its walls of a Research Laboratory in which Professor Dunstan and

his assistants are busily investigating the chemical nature of numerous interesting products obtained from all parts of Greater Britain.

There can, in my opinion, be no doubt that this much extended cultivation of scientific chemistry in this country, which is such a noticeable feature of the concluding years of the nineteenth century, has been greatly assisted by a most fortunate, and more or less accidental, circumstance, without which the energy and enthusiasm of our chemical teachers would have been seriously restricted in their influence. I refer to the very substantial surplus, producing an income of 6,000*l.* to 7,000*l.* a year, of which the Commissioners of the 1851 Exhibition found themselves possessed, and its utilisation on the advice of the late Lord Playfair for the purpose of the Research Scholarships which have for some ten years past been so highly prized by all the educational institutions permitted to participate in them. The good wrought by these scholarships has been very far-reaching, and it would be difficult to praise too highly the wisdom displayed by the Commissioners in drawing up the conditions on which they are awarded. Firstly, by not limiting them to any one science, they have stimulated a wholesome rivalry between departments to bring on their promising students to the level of scientific investigation. Secondly, they have compelled the governing bodies of educational institutions to recognise and make provision for research as part of the regular programme of these places. Thirdly, they have encouraged talented students to devote an additional year, or even more, to their education in the hope of securing one of these prizes; and these students have thus provided their teachers with the *personnel* necessary for carrying on scientific work. Fourthly, the scholars themselves have had the inestimable advantage of extending their horizon, and of coming in contact with other teachers, other schools of thought, and other views of life. Fifthly, these scholars on their return, and before they have obtained definite employment, are welcomed as supernumeraries in English colleges, where they have an opportunity of continuing their researches, and where they assist in imbuing the students with the spirit which they have themselves imbibed. Lastly, these and other scholarships of a similar character are providing the country with a body of highly trained men whose value to the nation is annually becoming more appreciated, and whose work will continue to bear fruit directly or indirectly for an indefinite period of time. These Exhibition scholarships have now been awarded since 1891, and already no fewer than sixty-five chemists, including three women, have enjoyed the enormous privilege of extending their education for a period of two, and in special cases even three, years under the most favourable surroundings.

Bearing in mind the rooted objection which pervades the people of this country to expend any public money on higher education, it is marvellous that it should have been possible to employ this fund, which after all is of a quasi-public character, for what may be described as educational use at a high potential, instead of its being dissipated in the manner so dear to Englishmen, by benefiting to an infinitesimal extent a much larger number of persons. Indeed, but for the vertebrate character of the Commissioners in 1877, the fund would have been thus frittered away, for in that year they were waited upon by a deputation of influential persons who urged that the money should be distributed in grants to provincial museums. Had that been done what would have been the result? The masses would have had a few more glass cases to gaze at on wet days and bank holidays!

There can, I think, be little doubt that in this matter of the allocation of funds intended for the public good we have reached a turning-point in the road which we have been so long pursuing. Until recently it has been the feeling of a very powerful majority in this country that public money should only be spent in such a way as to directly benefit very large numbers; and in the case of educational funds, therefore, it was only their utilisation for the benefit of the masses that could be entertained. Now, whilst it is indubitable that the improvement of our primary education was for many years a crying necessity, it has long been obvious to a minority that this policy is systematically starving that higher education in which we are lagging more and more behind those other countries in which greater elasticity prevails, and in which the immediate and obvious wants

of the community receive prompt attention without regard to the traditions and doctrinaire principles of a past generation. In the matter of higher scientific education, at any rate, it is becoming more and more widely recognised that its starvation through attention being exclusively directed to the low-level education of the masses is defeating the very ends which this policy has in view. Indeed, some practical men, and even a few statesmen, realise that the many are beginning to suffer from the results which this policy has had on our manufactures and commerce, without which the multitude can have no existence at all.

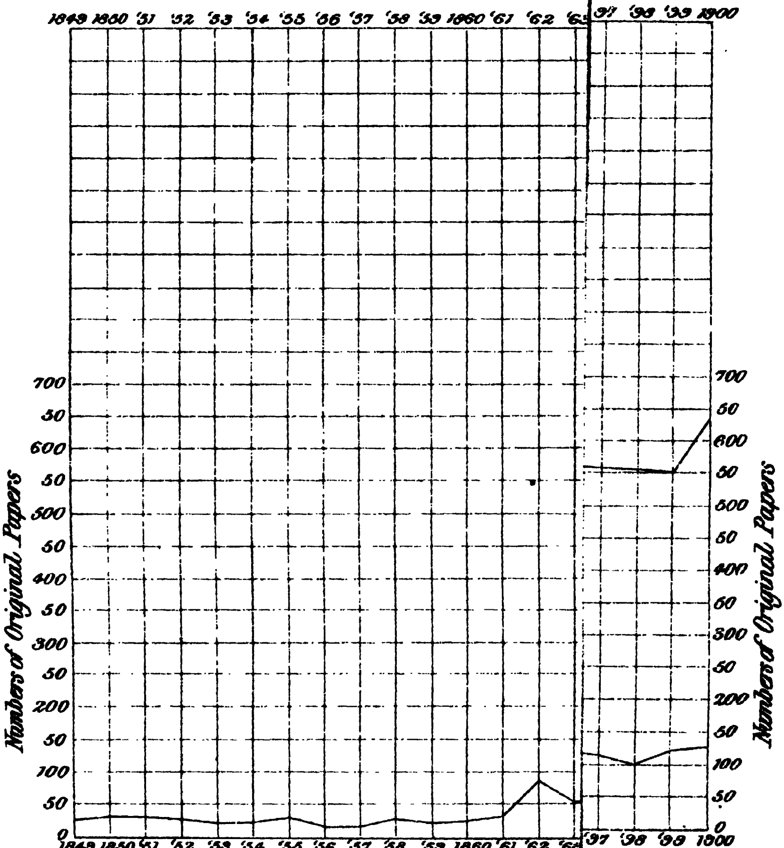
The more than princely patronage of higher education by that Scotsman who has not forgotten the land of his birth during fifty years spent in a country which has afforded the necessary scope for his genius and energies illustrates the change in the wind of opinion amongst practical men; for Mr. Andrew Carnegie's handsome contribution to the funds of the University of Birmingham, and his endowment of the universities of Scotland on a scale which is altogether without precedent, clearly show which, in his opinion, are the rungs in the educational ladder of this country that require strengthening in the interest of those very masses which it is his earnest desire to benefit. The still more recent response of the City Council of Birmingham to Mr. Chamberlain's suggestion that a rate should be levied in aid of the university of that city is further evidence that Mr. Carnegie's practically expressed opinion is shared by the enlightened rulers of that great municipality to which I have the privilege of belonging.

These, ladies and gentlemen, are, I believe, no mere sporadic manifestations, but unquestionably signs of the times. The opening of the new century is in reality a year of very serious awakening to those Englishmen who are not deaf to the voices in the air around them. It is rapidly dawning upon many that 'the greatest empire which the world has ever seen' cannot be maintained unless we cast off insular prejudices and traditions, and make a careful study of those points in which other nations are our superiors, with a view to the intelligent adaptation and development, as distinguished from mere imitation, of their methods to our own particular needs.

The survey of the British chemical world at the dawn of the twentieth century affords, however, scope for satisfaction in many ways. Not only have the places in which higher chemical work can be and actually is carried on been greatly multiplied, but the number of workers has been largely increased; and although the enthusiasm of these workers cannot well be greater than that of those who laboured so successfully twenty years and more ago, it has not become diminished and is certainly diffused more widely amongst the *personnel* of our colleges and universities. In this connection I need only remind you of the large number of active and independent investigators who are to be found amongst the members of the junior staff at almost every college in the country, and which is altogether without parallel in the past.

There are hardly any of the great problems now exercising the minds of chemists throughout the world which are not being worked at by some of our number; whilst that some chapters in the recent progress of chemical science are more or less specifically British, I would only remind you of the isolated labours of Dr. Perkin in the field of magnetic rotatory power; of Sir William Crookes's exploration of the phenomena occurring in high vacua; of the researches of Abney, Russell, and Hartley on the absorption spectra of organic compounds; of the investigations by Harold Dixon and Brereton Baker of the behaviour of substances in the complete absence of moisture; of the extension by Pope and Smiles of our knowledge of asymmetric atoms; of the near approach to the absolute zero of temperature by Dewar; and of those marvellous discoveries of Raleigh and Ramsay which have not only introduced us to five new aërial elements, but have revealed the existence of a hitherto unknown type of matter, which is apparently incapable of entering into chemical combination at all.

But whilst we may thus congratulate ourselves on this increased activity in chemical investigation, and upon the maintenance of a high standard of quality by the exceptional brilliancy of the researches of some of our number, we must now carefully consider how we stand with regard to the absolute quantity of our output



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I have called your attention to the evidence of activity in the British chemical world which is furnished by the number of original investigations communicated to the Chemical Society of London. Let me now ask you to turn to the corresponding picture, which is furnished by the statistics of the much younger Chemical Society of Berlin.

Original Communications to the Chemical Society of Berlin.

1868 .	. 97	1877 .	. 568	1886 .	696	1895 .	. 636
1869 .	. 252	1878 .	. 602	1887 .	708	1896 .	. 566
1870 .	. 277	1879 .	. 604	1888 .	658	1897 .	. 560
1871 .	. 288	1880 .	. 563	1889 .	601	1898 .	. 555
1872 .	. 303	1881 .	. 495	1890 .	630	1899 .	. 549
1873 .	. 420	1882 .	. 541	1891 .	677	1900 .	. 636
1874 .	. 516	1883 .	. 535	1892 .	553		
1875 .	. 488	1884 .	. 646	1893 .	587		
1876 .	. 517	1885 .	. 686	1894 .	653		

A comparison between these figures and those of the London Chemical Society is best effected by means of the diagram, which speaks for itself, and shows that chemical science occupies an entirely different place in Germany from that which it even now does in this country. The curves in the diagram bear, indeed, somewhat the same relationship to each other as do the homely elevations of the Grampians to the snow-clad peaks of the Andes.

Is this state of affairs to continue throughout the twentieth century? Are intellectual ambitions to be for ever subordinated to the extension of territory, to the acquisition of that metal which has had its atomic weight so accurately determined by Thorpe and Laurie, and to those other problems which fill the political horizon? Even the most recent awakening of interest in higher scientific education is not altogether of the breed to satisfy us as men of science; for the interest is assuredly not in the pursuit of knowledge for its own sake, but is aroused by the desire to secure those material advantages which it is beginning to be realised must inevitably result from the steadfast prosecution of scientific research. This is indeed a very different spirit from that which has led to the proud position occupied by science and learning of all kinds in Germany.

Schiller has truly said—

'Knowledge is to one a goddess, to another only an excellent cow.'

I fear there can be no doubt that here it is the cow, and not the goddess, that is in request. Thus, whilst in Germany the love and reverence for knowledge preceded the esteem of knowledge for the material benefits which it confers, we must hope that in our country the eagerness to secure the material advantages will perhaps lead to a love and reverence for that which confers them, so that in the course of time, perhaps, the useful cow will be allotted a stall on Olympus, or be at least pastured on the grass of Parnassus.

From whatever motive, whether utilitarian or otherwise, we wish to see the position of science in this country raised, and the qualitative and quantitative output of scientific work increased, I imagine that the methods to be immediately pursued for attaining this end must be very similar.

If the higher teaching of science is to be really encouraged the first necessity is that this higher teaching shall offer a sufficiently attractive career to the man of ambition as well as to the enthusiast. We all know that the supply of enthusiasts of intellectual power combined with capacity to perform is extremely limited and wholly inadequate for carrying out the important work of the world, and that the greater part of such work is actually done by men of ambition.

In order that the academic world may attract the ablest men of ambition as well as that *rara avis*, the able enthusiast, it is necessary that the highest prizes for academic distinction should carry similar social prestige, similar remuneration,

and similar opportunities of exerting public influence as are enjoyed by the leaders of other professional callings: they should be at least equal to those of the Archbishop of Canterbury or of the Lord Chancellor. It is not by any means necessary that such prizes should be numerous, as is abundantly demonstrated by the volume of able ambition which is drawn into the Church and to the Bar by the comparatively few opportunities for great success in those professions. The enthusiasts already find their way into the academic world; and, although they maintain the quality of British scientific work, they are unable, by virtue of their scarcity, to maintain the quantity which is essential for the luxuriant growth of science in our midst, whilst the absence of such tangible rewards as are bestowed in other spheres of intellectual activity prevent the importance of science being recognised by a public which has no appreciation of the inward and spiritual grace unless guided by the outward and visible sign.

Precisely the opposite policy, as far as remuneration is concerned, has, however, been pursued in the academic world during recent years, the few very moderate prizes which formerly existed having been deliberately commandeered to more nearly equalise the value of the chairs in all departments.

The principle of equalising the remuneration of different chairs is as inequitable as it is utterly unsound from a business point of view. The principle is unsound because equal salaries will not secure men of similar standing in different subjects, it is inequitable because the amount of work attaching to the chairs of different subjects is necessarily very unequal, as is the order of intellect required for the successful discharge of their duties.

Again, the system which is gaining ground in this country of allocating a certain stipend to a chair is unbusinesslike and mischievous. It is as irrational to fix the remuneration of a particular chair as it would be to fix the price to be paid for one's portrait, irrespectively of whether it were taken by a photographer or painted by a Royal Academician. If we really want the best man for any particular professional service, whether it be to treat us for a disease, to plead our cause in a court of law, or to perform on some musical instrument for our delectation, we know that we must make up our minds to pay the price which the best man commands in his particular profession, and it is absurd to suppose that the same principle does not hold good in the matter of securing the best man for an academic appointment. This, again, is intimately connected with the desirability of providing a sufficient number of steps in the academic ladder, so that it shall not be possible for the 'young man of promise' to be rushed into a first-class appointment from which he has no ambition to move for the remainder of his days.

Another matter, again, requires consideration: if we are really in earnest in the attempt to bring our universities abreast of those in other countries, our chairs must be systematically thrown open to the whole world, and the best men obtainable secured, irrespectively of their nationality. Not only have small nations adopted this plan, but even the nation which is pre-eminent for its academic strength is by no means blind to the importance of drawing into its service from the outside men of commanding brilliance and power. I need not remind you that England has also exhibited a wise and liberal spirit in this matter in the past, and that, as far as our science is concerned, this policy has been most fully justified. For, consider only what the English Chemistry of the latter half of the nineteenth century owes to the genius and magnetic influence of the imported Hofmann. I can imagine the electors to British chairs suggesting that there might be linguistic difficulties in the way of carrying out such a policy, in answer to which I would appeal to the pupils of Hofmann to say whether his stimulating discourse lost anything of its vigour and inspiration through the strong Hessian accent with which every word of it was saturated. It is to be hoped that no narrow and short-sighted policy, disguised under that too often misused word 'patriotism,' will seek to close the doors of our universities to the genius and ability of other nationalities.

I believe, however, that one of the most urgent and pressing of University reforms is that greater facilities should be afforded for the migration of students

from one university to another, without prejudice to their acquisition of a degree. It is the present system, which practically chains an undergraduate with links of steel to the university at which he matriculates, that is at the root of many of the evils under which our higher education is labouring.

The university at which a youth matriculates is often determined by the fatuous, although pathetic, wish of the father that his son should spend his time, I will not say work, amidst the surroundings which awaken such pleasant memories in himself; and the youth once within the magic portals has little or no opportunity of rectifying the possible mistake of his fond parent, who has probably for a quarter of a century been quite out of touch with university matters, or even divorced from the intellectual world altogether.

This foolish sentiment of loyalty to a university or even college is sometimes kept up for generations, and I have met persons who have told me that their family had always been Balliol or Trinity men, with the same sort of pride that they would doubtless have informed me, had they been able, that their ancestors came over with the Conqueror or had charged with the Cavaliers at Naseby.

The prevalence of such a sentiment shows that our universities are principally valued for their social attractions, as well as for their past history and ancient traditions, in which connection it is always well to remember that a living dog is better than a dead lion.

The possibility of students dissociating themselves from the university of their matriculation and freely migrating from one school to another would, in my opinion, not only be of immense advantage to the students themselves, enabling them to obtain the best instruction in each particular subject and greatly extending their horizon and knowledge of the world, but it would operate most favourably on the universities themselves, minimising the tendency to stagnation, and compelling those who hold the purse-strings to provide for the strengthening of weak departments. Nor should the possibilities of migration be limited to the Universities of the United Kingdom or even of the British Empire, but the prospect should be kept in view of ultimately effecting an arrangement whereby students could enjoy the advantage of visiting the universities of other countries.

Such migration is, of course, closely connected with the duration of the period of university study, and in this matter reform is most urgently needed. The traditional three years devoted to the acquisition of a degree is hopelessly inadequate for the higher purposes of university training, especially when the very immature age at which English students generally begin their university career is taken into consideration. The period of academic study should be forthwith extended to five years, as it is only in this way that the university can be effectively made a centre of research. Without a course of study of such duration, and of which research forms a part, it is quite impossible that the highly trained men who are now so urgently needed for practical avocations should be produced.

In this connection, again, we all know that much mischief has been going on in recent years. Instead of the terms on which degrees are at present obtainable being regarded as too lenient and easy, proposals are actually being put forward in some quarters to enable persons attending evening classes to thereby qualify for university degrees. Now, whilst it is of the utmost importance to provide abundant opportunities for the talented poor to obtain a university education by reducing the fees and by instituting a sufficient number of bursaries, it is imperative that those who are to be stamped with the distinctive mark of a university should have devoted their whole and undivided attention, over a certain period of time, to the courses of study prescribed. Let us beware of introducing the half-time system into the university, a system which we know to be a deplorable makeshift even in the elementary school.

In this matter of the aspirations, scope, and functions of a university we have not merely to contend with the ignorance and apathy of the average Philistine, but we are wrestling against principalities, against powers, and against darkness in high places. Thus only four months ago one of our most prominent statesmen, whose oracular and sporadic utterances inspire amongst millions almost the

awe and respect which is felt for the supernatural, is reported in the columns of the daily papers to have said at one of the most important educational gatherings of this first year of the new century:—'You, Mr. Vice-Chancellor, spoke of the stigma that would rest on the University if it did not annually produce some work of original research. I, from another point of view, am contented if you do nothing of the kind. I am satisfied to think that in a large and increasing degree you will train men and women fit for the manifold requirements of this Empire.' This statesman, who it is not surprising to find was educated at Eton and Oxford, is thus of the opinion to-day, unless, indeed, his views have changed in the interim, that it is possible to train men and women fit for the manifold requirements of this Empire without bringing, at any rate, some of them into contact with the living spirit of research—that spirit which, operating through the ages, has enabled man to transform the wilderness in which he was placed by his Creator into the garden of material and intellectual enjoyments in which that statesman was himself born.

I would ask you to contrast with the views of the distinguished *alumnus* of Eton and Oxford the utterance of another statesman who, unhampered by such educational antecedents, has formulated the following ideal for the guidance of that university which he has himself created:—

'The third feature to which I should call attention, and which, I am inclined to say, is of all the most important, is that a university should be a place where knowledge is increased, and where the limits of learning are extended. Original research, the addition of something to the total sum of human knowledge, must always be an essential part of our proposals.'

Lastly, we have to consider whether this university work, in which we hope for such great developments in the twentieth century, is still to be carried on by what is virtually private enterprise and private endowment, or whether it is to be provided for by taxation.

If the reforms and developments which are being preached from so many platforms are to be really carried out, if even our higher scientific training alone is to be brought into line with that which is provided in many other countries, it is indubitable that expenditure will have to be enormously increased. Now, profoundly as we all admire the enlightened public spirit of the men and women who have in the past endeavoured out of their private resources to help forward the great movement of higher education, it is, I believe, the firm conviction of all who have any real knowledge of what this higher education means, and a clear conception of what must be done in order to put it on a proper footing in this country, that on private benefaction alone this work cannot be accomplished. But even if private endowment could raise this great edifice in our midst, it is obvious that we should have to wait indefinitely for its realisation. Voluntary contributions cannot be made to come at the bidding of those who stand in need, nor directed into the channels where they will produce the most good; they have to be patiently waited for, with the result that valuable time is lost and opportunities pass by never to return. Private benefaction, moreover, is almost always retrospective: a hospital is not founded by the charitable until the sick are dying unattended; almshouses and orphanages are not thought of until the widow and the fatherless are either starving in the streets or begging on the doorstep. What we so forcibly recognise in this matter, however, is that we have not only to make up for leeway in the past, but that we must now exercise prevision to prevent similar disastrous lapses in the future. The state of affairs to which we have been reduced must not be allowed to occur again; the warnings of those possessing special knowledge in these matters must not be disregarded in the future as they have been in the past, for it is no exaggeration that the whole of the learned societies and academic bodies of this country put together have at present a smaller corporate share of political influence than a Temperance League or a Trades Union. To what has this state of things reduced us? The humiliating spectacle of 'the greatest empire the world has ever seen' at the beginning of the twentieth century without a teaching

university in its Metropolis, and engaged upon the task of tardily patching one together out of those heterogeneous elements of uncertain valency which are to hand. Is the completion of this structure, on a scale challenging comparison with the universities which are to be found in the other great capitals of Europe, to be delayed until a millionaire, or rather series of millionaires, can be induced to finance it? To this work, and to other works like it, is it not fitting that every inhabitant of this country should contribute? For these are works which assuredly benefit all classes, not only of this generation, but of those which are to come—at least as much as the acquisition of territory at a distance of 8,000 miles from home, and for which purpose the nation is apparently willing to pay at the rate of one and a quarter million sterling per week for an indefinite period of time.

It is sometimes urged that this higher education does not benefit the masses; but could any contention be more erroneous? The poor have really a far greater stake in the prosperity of our home industries and commerce than the rich; for whilst the decay of our producing power will remove the very means of subsistence from the poor, it matters very little to many of the rich whether their dividends are derived from home-enterprises or from those of a Billion Dollar Combine or some similar transatlantic Trust or Corporation.

Higher education and true universities are also amongst the most potent factors in breaking down the hereditary stratification of society and in minimising the advantages depending upon the accident of birth, so that, with the greatly enhanced facilities which must be provided for students without means, they should afford in the future, even more than they have done in the past, an avenue for the humblest boy of talent to that position which he is by natural endowment and by his own exertion best fitted to fill in the interests of the State.

Is this great work of raising up a worthy system of national higher education, and of creating a living interest and widely diffused enthusiasm for knowledge and for the increase of knowledge in all its branches, going to be accomplished during the century of which we have but crossed the threshold? Even the most sanguine among us dare not unhesitatingly say Yes; but assuredly upon the answer, which is hidden by the veil of the inscrutable future, depends in the very highest degree, not only the material and intellectual welfare of the rising generations, but also the good name and reputation of the Empire in our own time and the gratitude which, above all things, we should strive to earn from that immortal part of us which we call Posterity.

The following Papers and Report were read:—

1. *Duty-free Alcohol for Chemical Research.* *By* W. T. LAWRENCE.

'*The present occasion seems opportune to direct attention to the fact that one of the most familiar, most readily procurable, and most cheaply produced of all organic material is placed beyond the reach of many students by the heavy duty levied upon it. May I, in the name of teachers of organic chemistry, appeal to the Board of Inland Revenue, on behalf of scientific and technical education, to provide institutions for higher education in science with a limited quantity of pure alcohol free of duty, thereby placing schools of chemistry in this country in the same position as those on the Continent?*'—Dr. JULIUS B. COHEN, 'Practical Organic Chemistry,' Introduction, p. vi.

The remarkable success attained by the Baden Soda and Aniline Factory in the modification and commercial adaptation of laboratory syntheses, a success which has lately resulted, after some nine years of experimental work, in the manufacture of indigo, &c., has demonstrated that organic research work, which possessed at the time a merely theoretical interest, may ultimately find valuable application in the chemical industry. English manufacturers have gradually awakened to an appreciation of the value of research, and the chemist who has published a considerable amount of original work will command a high

salary and, having demonstrated his ability to tackle intricate problems, will be consulted when difficulties arise.

To give an example, a large firm of manufacturers in the north of England, finding that certain of their comestibles products lost their colour on keeping, instead of communicating with a firm of analysts, consulted an organic chemist, who possessed little or no experience of commercial organic analysis, but whose experiments and researches showed that he would consider the question with an innate knowledge of the subject, unfettered by rule of thumb. The decision of the manufacturers proved a wise one.

The majority of young men engaged in organic research possess restricted incomes—£100–150 shows a fair average—consequently the expense of materials falls heavily on them. Such research frequently demands the use of large quantities of dutiable articles—absolute ethyl and methyl alcohols, methyl iodide, &c. Now the duty on alcohol is a consumption tax the objective of which is tersely put in the following sentence from the official Customs tariff, 'including naphtha or methylic alcohol *purified so as to be potable*'; but it was certainly never the wish of any administration to tax experimental science and the industries which result from these experiments.

A good instance of the absurd length to which the Customs authorities are prepared to go appeared a few weeks since in the papers. A collection of crustaceans preserved in spirit was sent from India to Mr. Beddard, the eminent F.R.S.; the Custom House wished to charge Mr. Beddard 25*s.* duty because the spirit in which these crabs and crayfish were preserved had not been methylated, and was consequently, we can only suppose, considered potable. I am glad to say the alcohol was poured away, and consequently the duty was not paid.

The following figures from the Owens College Chemical Laboratory show the amount of duty paid in the course of one year on methyl and ethyl alcohol alone:—

Duty paid in 1896–7	£43 16 0
" " 1897–8	£56 0 0
" " 1898–9	£44 10 0

The duty represents about 2·15 times the original value of the alcohol.

Practically the whole of the alcohol purchased by the laboratory used by three or four chemists engaged in organic research: thus the ledger debits from October to April 1900–01 three chemists with 11*l.* 8*s.*, 6*l.* 18*s.*, 5*l.* respectively for alcohol; we may therefore consider that these three chemists pay roughly 50*l.* a year for alcohol, of which sum about 16*l.* 10*s.* is the actual value of the alcohol, and the rest is made up by the duty.

The distinct disadvantage at which the English chemist works, as compared to his Continental colleagues, is shown by the following statement kindly supplied by the Commercial Intelligence Department of the Board of Trade:—

'So far as the information in the possession of this branch goes, there would appear to be no free admission of alcohol from abroad for industrial purposes in either of the countries[1] named. There are internal taxes in both countries from which alcohol is, under certain circumstances, exempt; but it does not appear that the exemptions affect the imported article, unless possibly in one instance, as will appear later.

'In France the internal tax of 220 fr. per hectolitre of pure alcohol is a consumption tax from *which alcohol used for industrial purposes is exempt, being subject only to a statistical tax of* 25 *centimes per hectolitre of pure alcohol.*

'On imported articles, in which alcohol exists, the consumption tax is levied (in addition to Customs duty) on the amount of pure alcohol which exists in a state of simple mixture or chemical combination, and it is not absolutely clear whether if such articles are to be used for industrial purposes they would be exempt from this tax. The statistical tax on articles in which the alcohol has been entirely transformed, eliminated, or evaporated (*e.g.*, ether), plus 80 centimes per hectolitre, to compensate for the expenses of surveillance, &c., incurred by

[1] France and Germany.

French manufacturers, is, however, levied on the amount of alcohol calculated to have been used in their production. In Germany alcohol used for industrial or medicinal purposes is exempt from the tax on the production of spirits (*Brantweinstener*).'

The above remarks apply equally to alcohol used in chemical research.

One of the objections which will possibly be raised by the Treasury in refusing to move in this matter is that though a great proportion of the cost of organic research in this country is due to the high cost of duty-paid alcohol and ether, yet they (the Treasury) pay back to chemical science far more than they receive from chemistry as duty. It has been suggested that the organic chemistry department of the Owens College has been peculiarly favoured in the administration of the Treasury grant. Here are the facts. In the year 1898 the chemical department of the Owens College received 175*l.*, and in the year 1899 125*l.* in Treasury grants; against these items we find that the College in the year 1899–1900, though suffering severely from the financial depression, paid 427*l.* 15*s.* 10*d.* for apparatus and chemicals used in research, the result being that 20 per cent. of the transactions of the Chemical Society for 1899 are occupied by contributions from the College laboratories. It is well here to point out that the tax falls most heavily on students who, having just taken their degrees, are engaged in their first researches. Such students, as a rule, receive no pecuniary assistance.

Does not the Treasury grasp the elementary principle that the advance of knowledge, leading, as it does, to the creation of new industries and to the perfection of the old, becomes a valuable, if indirect, source of increased income?

The Board of Inland Revenue are understood to object that the administration of a remission of the duty in alcohol would be both complicated and costly.

Is this difficulty really so insuperable? In France, as has been shown, the cost of administration is met by a statistical tax. In this country a precedent has been set in the permission of responsible persons to use and recover methylated spirit.

'A person desirous of using methylated spirit must make written application to the Commissioners, stating the situation of the premises, the particular purpose or purposes to which the spirits are to be applied, the quantity likely to be required in the course of a year, and if the quantity to be used in a year exceeds fifty gallons, or there is a still on the premises, or means are adopted for the recovery of the spirits after use. He must furnish the name of one or more householders or of a guarantee society to join him in a bond for the proper use of the spirits.'

In America and Canada colleges and institutions are permitted to use alcohol free of duty on a signed requisition from the head of the college or department. Should this suggestion be adopted or not?

A modification of the following scheme might be found workable. Institutions and laboratories desirious of using pure alcohol for scientific purposes might apply to the Board of Inland Revenue for a licence (for which, say, a charge of 5*s.* to 10*s.* could be made); the manufacturer or retailer supplying the alcohol in this country would with the delivery note send a form which could be filled up and signed by the director of the institution or laboratory, and the manufacturer or retailer would ultimately obtain remission of duty from the Inland Revenue Board on presentation of these forms as *bona fides*. In the case of alcohol coming from foreign countries the usual Customs note would be so modified that the consignee would be able to apply direct for rebate. If the Board of Inland Revenue consider supervision of such institution and laboratories necessary, it surely would not entail much extra work on those officials who now control the use of methylated spirit.

What steps can be taken to obtain this object? It is first necessary to ascertain whether to effect such a change would be within the statutory powers of the Board of Inland Revenue, or whether it would be necessary to introduce a Bill into Parliament.

In the first case it seems to me that an influential deputation might wait on he First Lord of the Treasury or the Chancellor of the Exchequer and represent

to him the facts of the case. In the second case the question becomes more complicated.

My view—a view shared by many eminent chemists present at this meeting—is that it would be highly advantageous to appoint a small committee to consider the question and to report on it.

The intention of this article has been to again call attention to a subject which, though frequently the object of fruitless endeavours, yet by its very reasonableness deserves success. Organic chemists will find that they will have to present a very strong case, influentially backed, before they can persuade such officials of the Treasury and Board of Inland Revenue as do not possess the scientific mind to recognise the importance of the subject; yet the time is coming when

'the thoughts of men are widen'd with the process of the suns.'

2. *The Coal Tar Industry.* *By* Dr. A. G. Green.—See Reports, p. 252.

3. *Report on a New Series of Wave-length Tables of the Spectra of the Elements.*—See Reports, p. 79.

FRIDAY, SEPTEMBER 13.

The following Papers were read:—

1. *Enzyme Action.* *By* Adrian J. Brown.

The author has already shown[1] that in alcoholic fermentation a *constant weight* of sugar is decomposed in unit time by a constant amount of yeast in solutions containing different amounts of sugar, and has called attention to the fact that in this respect the action of fermentation differs essentially from that of inversion, which, according to C. O'Sullivan and Tompson, follows the law of mass action.[2]

So long as the phenomenon of fermentation was believed to be a life function inseparable from the living yeast cell, it did not appear remarkable that the order of progression of its action should differ from that of inversion; but since Buchner has shown that fermentation, like inversion, is an enzyme action, this point of difference required further investigation.

The author has examined the action of invertase on cane sugar experimentally, and demonstrates that the action as usually studied does not follow the law of mass action, but resembles that of fermentation.

The curve of action of invertase found by C. O'Sullivan and Tompson does not instance mass action, but, as suggested by Duclaux,[3] its form is due to the arresting influence of inversion products. J. O'Sullivan's experiments[4] on the power of inversion of living yeast cells are referred to, and it is shown that the results of his experiments also confirm the author's conclusion.

But although the action of inversion as studied by C. O'Sullivan and Tompson, J. O'Sullivan, and the author does not follow the law of mass action, the author does not regard the action, however produced, as independent of mass influence, and considers that the influence of mass in inversion changes as it has hitherto been studied is restricted by some other influence. This influence he believes exists in the time factor of molecular change.

[1] *J. Chem. Soc.*, 61, 1892, 380.
[2] *Ibid.*, 57, 1890, 865.
[3] *Ann. Inst. Pasteur*, 1898.
[4] *J. Chem. Soc.*, 61, 1892, 926.

In any simple chemical change the influence of mass regulates the number of molecular *contacts* between acting and reacting molecules in unit time; but if a time factor enters into the molecular reaction, there must be a point beyond which the number of molecular *changes* cannot increase owing to the restriction of time in the action, and this point will be determined by the relative frequency of molecular contact and the length of the time interval of molecular change.

There is good reason to believe that during inversion of cane sugar the sugar enters into molecular combination with invertase previous to change, which presupposes a time factor of some magnitude. Under these conditions it therefore appears the more probable that this factor limits the effect of mass action in inversion changes as observed in solutions of ordinary concentration. But if this is so, there must be a point of dilution in cane sugar solutions when invertase, acting in the dilute solutions, exhibits an order of change in conformity with mass action. The author shows by direct experiment that this point is reached in a solution containing about 1 per cent. of cane sugar, so far confirming his conclusion that the time factor of molecular change limits the action of inversion in all but very dilute solutions of cane sugar.

As the character of the action of fermentation has been shown to resemble that of inversion, it appears very probable that in this enzyme change also the time factor of molecular change limits its action; and possibly the influence may be evidenced in all enzyme change, and so play an important part in the complex functions of living organisms which depend on enzyme action.

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2. *Radium. By* Professor W. Marckwald.

The Section was then divided into two Departments.

Department I.

The following Report and Papers were read:—

1. *Report on the Relation between the Absorption Spectra and Chemical Constitution of Organic Substances.*—See Reports, p. 208.

2. *On the Chemical and Biological Changes occurring during the Treatment of Sewage by the so-called Bacteria Beds. By* Professor Letts, *D.Sc., Ph.D., and* R. F. Blake, *F.C.S., F.I.C.*

It is generally assumed that the so-called 'bacteria beds' act as oxidising agencies, absorbing oxygen from the air during their periods of rest and subsequently transferring it to the constituents of the sewage when the beds are filled with this latter, the transfer being effected by micro-organisms which have established themselves on the surface of the material with which the beds are filled.

It also appears to be generally taken for granted that the micro-organisms mainly concerned in the purification process are the nitrifying organisms. Hence if these views are correct, the effluent from the bacteria beds should contain nitrates and nitrites equivalent in amount to the unoxidised nitrogen which disappears during the treatment. But on examining the results obtained by chemists in investigations on sewage purification it will be found that comparatively small amounts of nitrate and nitrite are produced in relation to the unoxidised nitrogen disap----.

he following figures are taken (or have been calculated) partly from results given in the Manchester Report of the Rivers Committee, January 22, 1900,

Table 1, the Leeds Report on Sewage Disposal, December 1898, Table 1, and partly from the table (p. 68) given in Dibdin's book on the 'Purification of Sewage and Water.'

—	Nitrogen disappearing as 'Free' and 'Albuminoid' Ammonia	Nitrogen found in the Effluent as Nitrate and Nitrite after double contact with the Bacteria Beds	
	Grains per Gallon	Grains per Gallon	Percentage on Nitrogen disappearing
Manchester	1·634	0·636	39
Sutton	7·185	1·100	15
Leeds	1·528	0·11	7

It is quite evident, therefore, that a considerable portion, and in most cases the greater part, of the unoxidised nitrogen which disappears must be got rid of in some other form, and the question arises as to how this may occur. In all probability there are two—and only two—alternative ways in which the nitrogen can be lost, viz.—

(1) It may escape in the gaseous state as free nitrogen, or possibly as oxides of nitrogen.

(2) It may pass into the tissues of animals or vegetables, the former of which may escape from the bacteria beds, and the latter (and possibly the former also) may remain permanently in the beds.

In other words there may be either a chemical or a biological explanation, or both together.

Chemical Explanation.—In an investigation on the effects of double contact with bacteria beds on screened and settled sewage the authors made analyses of the dissolved gases present, both in the original sewage and in the effluent from both beds, the samples being collected in such a manner that they did not come into contact with the air.

The general results of these analyses were as follows:—(1) Practically no oxygen was present, either in the sewage or effluents. (2) The effluent from first contact always contained considerably more carbonic anhydride than the original sewage, and with two exceptions the effluent from second contact also contained an excess of that gas. (3) In eleven out of twelve series of analyses the quantity of nitrogen in the effluent was in excess of that present in the original sewage, and generally speaking it was in larger excess in the effluent from double contact than in that from single contact.

As the first six series of analyses only were made under exactly the same conditions, the authors find that, taking them as the basis of calculation, on the average the excess of nitrogen in the effluent from second contact over that present in the sewage amounted in weight to 0·272 part per 100,000, while the loss of unoxidised nitrogen which had occurred in the sewage (by Kjeldahl's process) amounted to 2·2 parts, or that 12 per cent. of the nitrogen lost from the sewage during purification was thus accounted for, while in one particular case it amounted to 31 per cent.

In all probability only a fraction of the free nitrogen actually evolved would be retained by the effluent, the rest escaping into the air.

Biological Explanation.—As regards the possibility that nitrogen is lost biologically, *i.e.*, is absorbed into the tissues of animals or plants which feed on the sewage, there can be no doubt that a portion does escape in that way. The bacteria beds at Belfast and elsewhere swarm with minute insects (*Podura aquatica*). These, escaping in myriads, often form a thick layer on the surface of the effluent, which looks like soot. There can be no question that in thus escaping these

animals carry with them some of the nitrogenous constitutents of the sewage which they have devoured, but as yet the authors have formed no estimate of the quantity so removed. There are also species of worms always present in the bacteria beds in considerable numbers which no doubt also feed on the sewage.

3. *Humus and the Irreducible Residue in the Bacterial Treatment of Sewage.* *By* Dr. S. Rideal.

4. *Sulphuric Acid as a Typhoid Disinfectant.* *By* Dr. S. Rideal.

5. *On the Inverse Relation of Chlorine to Rainfall.* *By* William Ackroyd, *F.I.C.*

Rainfalls of various dates when compared among themselves appear so erratic in their quantitative composition that observers have generally been satisfied with monthly or half-yearly averages. When the periods of observation are shortened to daily estimations, say of the chlorine, it clearly appears that minimum amounts of rainfall are marked by maxima of chlorine contents, and *vice versa*. Thus in a daily comparison where the results are plotted for tenths of an inch of rainfall and parts per 100,000 of chlorine the respective curves interlock and each chlorine peak has its corresponding rainfall hollow. This will be seen on following the plotted observations in the diagram for Halifax, November 12, 1900, to March 7, 1901. It is also apparent in the diagrams for country rainfall which illustrate my paper 'On the Distribution of Chlorine in Yorkshire, Part II.,' and where the observations are weekly. Marked parallelism of chlorine curves, where several are compared, is regarded as being due to common causes.

6. *On the Distribution of Chlorine in Yorkshire, Part II.* *By* William Ackroyd, *F.I.C.*

All figures refer to parts of chlorine per 100,000 of water.

As the result of many observations of minima, the chlorine is found to increase from ·7–1 in the west and north-west, where the rivers originate, to 1·7–2 in the east and south-east, where, in the Chalk Wolds, the upturned edges of the chalk drink in and store up a vast amount of rain water, which is utilised by many of the East Riding communities. Beyond this there is a south-eastern area of high chlorine figures formed by the triangular tract of drift ending with Spurn Head.

Normal chlorine is affected by manufacturing centres. From observations extending over three months, it is shown that in a manufacturing town like Halifax the atmospheric contribution through the rain is ·01 part of chlorine per 288 people per square mile, and that the total contribution for ground as well as air is ·01 part of chlorine per 53 of the population.

Attention is also drawn to a disturbing influence in the prevalence of high winds from the sea, which send up the chlorine figures for the rainfall.

Department II.

The following Papers and Report were read:—

1. *Hydration of Tin, including the Action of Light.* *By* Dr. J. H. Gladstone, *F.R.S.*, *and* George Gladstone.

The authors described a tin trade mark which had been standing in the mineralogical cabinet of Mr. George Gladstone for twenty-seven years, exposed on the front

to diffused daylight. The whole of the exposed surface was very dark in colour, especially where the exposure was most complete. On examining it under the microscope it was found to be covered with little granules varying in colour from yellow to dark reddish-brown. Where the dark granules were thickest there were found small yellow lumps that had all the appearance of colloidal matter. Some of this was removed and treated with water. The microscope revealed a quantity of light-coloured translucent films; the edges of the drop of water on evaporation showed imperfect colourless crystals resembling closely those obtained from other specimens of tin colloid, together with gelatinous matter. It was evident that there had been a slow chemical change, greatly due to the action of light, as the back of the trade mark, which was practically in the dark, showed very little discoloration. In order to see whether this could be repeated within a short time, three experiments were made on freshly cut surfaces of tin. The first was kept in the dark for six weeks, and sometimes subjected to a temperature of 100° C.: under the microscope it showed no clear sign of any action. The second was exposed for the same time to diffused daylight: it showed slight but unmistakable signs of granular formation. The third was exposed to direct sunlight: it was distinctly spotted over with dark-coloured granules.

2. *Transitional Forms between Colloids and Crystalloids.* *By* Dr. J. H. GLADSTONE, *F.R.S., and* WALTER HIBBERT, *F.I.C.*

The investigation of the crust formed on the tin trade mark referred to in the previous paper induced the authors to carry the inquiry further. Among the remains of the ancient British village near Glastonbury, which had been submerged in the marsh for 2,000 years, were the rod and weights of tin described in the British Association Report for 1899, p. 595; and an examination of the crust formed on these objects showed the gradual formation of yellow, amber, and reddish-brown hydrates, together with minute egg-like bodies, which, when broken, were found to contain gelatinous matter soluble in water, and giving on evaporation crystals having curved edges. The crystals are very definite in form, but are generally colourless and hygroscopic. A specimen of native cassiterite gave similar results; and so did colloidal tin hydrate formed from stannic chloride by dialysis. Colloidal hydrate of titanium gave intermediate bodies closely resembling those of tin. The same was found to be the case with aluminium and palladium colloids. No similar forms have yet been obtained from silica; but it is well known that quartz crystals, diamonds, and ice are apt to exhibit curved edges and conchoidal fracture.

The authors regard these semi-crystalline bodies as intermediate forms betweeen the gelatinous colloids, whether pectised or not, and the ordinary crystallised metallic hydrates. They look upon them as consisting of the hydrate combined with many molecules of water, and think that the various kinds of crystals (crosses, fishes, rhombs, &c.) are due to different amounts of combined water, as they show different degrees of solubility and of diffusibility. The isomorphism between these hydrates of tin, titanium, and aluminium is worthy of notice.

The secular changes that take place in these gelatinous hydrates, and the formation of the insoluble films, are the subject of investigation at the present time.

3. *Report on the Nature of Alloys.*—See Reports, p. 75.

4. *The Minute Structure of Metals.* *By* G. T. BEILBY.

Microscopic examination of metallic surfaces produced by breaking, tearing, or filing, by rolling, drawing, hammering, or polishing, has shown that the metals as they are ordinarily met with appear in two forms:—

(*a*) As minute granules or scales.
(*b*) As a transparent, glass-like substance.

These two forms of 'metal substance' occur in all of the metals examined, and taken together they do not appear to depend in any way on the particular thermal or mechanical treatment to which the metal has been subjected, nor on the greater or less mass of the particular piece of metal examined. Their existence is therefore to a great extent independent of the conditions which determine the particular crystalline structure of metals and alloys.

In form (*a*) the granules or scales do not vary much in size in the different metals examined, which include among their number representatives of most of the great groups. The diameter of the scales is estimated to range from $\frac{1}{300}$ to $\frac{1}{100}$ of a millimetre. Their thickness has not yet been measured, but they can be seen by reflected light when their thickness is certainly less than $\frac{1}{12000}$ of a millimetre.

Form (*b*) is seen as a transparent glass-like film on metal surfaces, which have been exposed to certain forms of pressure. In the transparent form the metals have their characteristic colours by transmitted light; for instance, gold is green, iron and platinum are blue, copper is red, nickel is olive green.

The scale form (*a*) passes into the transparent form (*b*) when the metal is pressed or hammered upon a hard polished surface. The same effect takes place when a mirror-like polish is produced by ordinary methods. Files or cutting tools in passing over the surface or through the substance of metals leave the cut or scraped surface covered with a more or less continuous film of transparent metal. By suitable treatment a coating of transparent metal can be formed of varying degrees of thickness, so that by reflected light scales can be seen more or less deeply imbedded in the transparent coating. The light from the deeper scales shows the characteristic colour of the metal. In some cases the colour of the coating appears so dense—as seen by the microscope—that no reflected light reaches the surface.

Attempts have been made to measure the thickness of the transparent film by focussing for its upper and lower surfaces, or for the upper surface, and for scales embedded in the film, and measuring the movement of the microscope between the two points. As these measurements appear to give rather exaggerated results their publication is held over for the meantime.

The transparent metal (*b*) passes back into the scale form (*a*) under certain kinds of mechanical or chemical treatment.

The metals already examined include gold, silver, platinum, cobalt, nickel, chromium, iron, copper, lead, bismuth, antimony, tin, cadmium, magnesium, aluminium, zinc.

The highly crystalline metals, such as antimony, bismuth, and zinc, exhibit the same features as the softer and more malleable metals. The crystalline faces and cleavage planes are covered with a film of transparent metal, while scales are distinctly seen in fractures at right angles to the cleavage planes.

Galena shows similar appearances.

The zinc and tin alloys of copper show the same minute structure and appearances.

The persistence of these minute scales under all kinds of mechanical and thermal treatment, the remarkable uniformity of their size and appearance in metals of all of the leading groups, their disappearance into the transparent form and their reappearance again apparently unchanged in size or otherwise—all this seems to afford fair ground for the conjecture that they are in some way definite units in the structure of metals.

5. *On the Action of Ammonia on Metals at High Temperatures.* *By* G. G. Henderson, *D.Sc., and* G. T. Beilby.

Platinum, gold, silver, copper, iron, nickel, and cobalt have been exposed to the action of ammonia at temperatures ranging from 600° to 900°. In every case the physical effect of the treatment was to disintegrate the metal completely, while a large proportion of the ammonia was resolved into its elements.

The fracture of metals which have been exposed to this action has been

described by earlier observers as 'crystalline.' This is not the case: it is spongy or cellular, and appears under the microscope as if it had been suddenly cooled while in a state of active effervescence.

The penetration of the ammonia molecule into the metal is remarkably quick. Iron and copper rods a quarter of an inch in diameter were completely penetrated to the centre in thirty minutes. But disintegration goes on almost indefinitely thereafter. Copper exposed for seven days to this action at a temperature of 800° became reduced to a fine spongy powder. The prolonged action on platinum produces very fine deposits of platinum black on the surface of the more massive metal.

The authors believe that the physical effects which result from this action are explained by the alternate formation and dissociation of the nitrides of the metals taking place between certain narrow limits of temperature, the reaction being turned in either one direction or the other according as ammonia or hydrogen molecules preponderate in the gases which are in contact with the molecules of metal at and below the surface.

It is suggested that the formation of spongy deposits on the outside of platinum crucibles heated by Bunsen burners, as well as the disintegration of the platinum wires of pyrometers exposed to furnace gases, may be accounted for by the presence of traces of ammonia in the combustion gases.

The absorption of small quantities of nitrogen by pure iron renders it hard and brittle like steel. Malleable iron tubes exposed for seven days to the action of ammonia at a temperature of 800° became so brittle that they could be broken like porcelain by a blow from a hammer.

It is suggested that some of the effects on the structure and properties of iron and steel which are at present attributed to other elements may be due to the presence of traces of nitrogen.

6. *Aluminium-Tin Alloys.* *By* W. Carrick Anderson, *M.A.*, *D.Sc.*, *and* George Lean, *B.Sc.*

This investigation was undertaken to ascertain, with some definiteness, the general properties of the alloys of aluminium and tin, and particularly the cause of the peculiarity, first pointed out by Riche,[1] that the alloy containing 25 per cent. aluminium evolves hydrogen freely when placed in water. This property was found to belong, not only to the particular alloy in question, but to the whole series, whether cast or annealed.

From the determinations of the cooling curves it is shown that tin dissolves in aluminium, but that in the case of alloys containing more than 10 per cent. tin a second break in the cooling curve takes place at 232° C., indicating an excess of tin.[2] Micro-photography was also employed to show the structure of the alloys in the cast and annealed condition. The amounts of hydrogen evolved from the several alloys, cast and annealed, were found to stand in no simple relation either to the weights of the constituent metals present, or to the depression in the aluminium melting point.

From microscopic examination of water-corroded plates the conclusion is arrived at that contact action between the tin and the stanniferous aluminium is mainly responsible for this spontaneous oxidation.

7. *Aluminium-Antimony Alloys.* *By* W. Campbell.

8. *Aluminium-Copper Alloys.* *By* W. Campbell.

[1] Riche, *Jr. Pharm. Chem.*, 1895, I. v.
[2] H. Gautier, *Comptes Rendus*, 123 [1896], p. 109.

SATURDAY, SEPTEMBER 14.

The Section did not meet.

MONDAY, SEPTEMBER 16.

The following Papers and Reports were read:—

1. *On the Three Stereomeric Cinnamic Acids.* *By* Professor A. MICHAEL.

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2. *On the Genesis of Matter.* *By* Professor A. MICHAEL.

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3. *On the Process of Substitution.* *By* Professor A. MICHAEL.

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4. *On the Synthetical Formation of Bridged-rings.* *By* Professor W. H. PERKIN, *F.R.S.*

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5. *The Condensation of Benzil with Dibenzyl Ketone.* *By* G. G. HENDERSON, *D.Sc.*, *and* R. H. CORSTORPHINE, *B.Sc.*

Benzil condenses readily with dibenzyl ketone in presence of aqueous caustic potash, and *tetraphenylcyclopentenolone* is produced according to the equation

$$\begin{array}{l} Ph.CO \\ | \\ Ph.CO \end{array} + \left.\begin{array}{l} Ph.CH_2 \\ \\ Ph.CH_2 \end{array}\right\rangle CO = H_2O + \left.\begin{array}{l} Ph.C=C.Ph \\ \quad | \\ Ph.C(OH).CHPh \end{array}\right\rangle CO$$

The new compound crystallises in colourless lustrous needles, m.p. 208°. It is readily soluble in benzene, but only sparingly in alcohol. It yields an *oxime* which crystallises in small colourless prisms, m.p. 167°, and when heated in alcoholic solution with parabromphenylhydrazine it gives a crystalline *hydrazone*, m.p. 169°. The *acetyl derivative* was obtained in prisms of a dark purple colour, from which the colouring matter could not be removed by recrystallisation: it melts at 218°. Tetraphenylcyclopentenolone readily decolorises permanganate, yet it does not combine additively with bromine, as might be expected from its constitution, but is slowly converted into an unstable *bromine derivative*, which was not obtained in a state of purity. It also reacts with phosphorus pentachloride and with alcoholic hydrogen chloride, but the product, which contained chlorine, was too unstable to admit of purification. When cautiously oxidised with chromic anhydride dissolved in glacial acetic acid it gives benzoic acid and a neutral *compound* of the formula $C_{28}H_{20}O_4$, which occurs in colourless crystals, m.p. 164°. When boiled under a reflux condenser with hydriodic acid and red phosphorus, tetraphenylcyclopentenolone is partially reduced and *tetraphenylcyclopentenol* $\left.\begin{array}{l} Ph.C=CPh \\ \quad | \\ Ph.CH.CHPh \end{array}\right\rangle CHOH$ is obtained. This substance crystallises in shining colourless needles, m.p. 162°. It is readily soluble in benzene, but very sparingly in alcohol, and it reduces permanganate. It does not react either with hydroxylamine or with phenylhydrazine, but it yields an *acetyl derivative*, which crystallises in colourless tablets, m.p. 182°. It does not form an addition product with bromine, but is converted into a *bromine derivative*, $C_{29}H_{22}Br.OH$, which crystallises in colourless needles,

m.p. 215°, and by the action of phosphorus pentachloride or of alcoholic hydrogen chloride it yields a *chlorotetraphenylcyclopentene*, $C_{29}H_{23}Cl$, in the form of colourless prisms, m.p. 181°. By heating at 180° in a sealed tube with hydriodic acid and red phosphorus, tetraphenylcyclopentenol is reduced, and yields a mixture of two hydrocarbons, $C_{29}H_{24}$ and $C_{29}H_{26}$, which can be separated by means of ether, in which the former is readily and the latter sparingly soluble. $C_{29}H_{24}$ separates from ether as a crystalline powder, which melts with decomposition over 300°. It is no doubt *tetraphenylcyclopentene* $\left.\begin{array}{l}Ph.C=CPh\\ \vert\\ Ph.CH\cdot CHPh\end{array}\right\rangle CH_2$. The other hydrocarbon separates in the crystalline state from alcohol. It melts at 80·5–81°, and is apparently identical with the tetraphenylcyclopentene $\left.\begin{array}{l}PhCH-CHPh\\ \vert\\ PhCH-CHPh\end{array}\right\rangle CH_2$, already prepared, in a different manner, by Wislicenus.

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6. *Some Relations between Physical Constants and Constitution in Benzenoid Amines. Part III.* By W. R. Hodgkinson *and* L. Limpach.

In the 'Proc. Chem. Soc.,' 1893, **9**, 41, we drew attention to some relationships between melting-points and constitution in some amines, and a further contribution by Gordan and one of us on the same subject appears in 'Trans. Chem. Soc.,' 1901, **79**, 1080.

Since then a considerable number of amines, their formyl and acetyl, and other derivatives have been prepared, it is believed, in as pure a state as possible, and their melting-points redetermined.

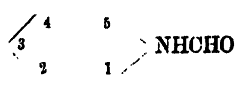
The first point noticeable is that the difference between the melting-points of the formyl and acetyl derivatives of bases of the same constitution is the same or very nearly so.

If in any base a methyl group be replaced by ethyl or oxymethyl (OCH_3) the melting-points of the formyl and acetyl compounds change, but the differences between them appear to be the same as between the formyl and acetyl derivatives of the methyl compounds.

The following will serve as instances:—

—	Constitution [1]	Melting-points: Formyl-compound	Melting-points: Acetyl-compound	Difference
Pseudo Cumidine . .	CH_3 CH_3 CH_3 2 3 5	121°	164°	43
Ethyl-ϕ-Cumidine . .	CH_3 C_2H_5 CH_3 2 3 5	103	145	42
Para-xylidine . . .	CH_3 CH_3 1 4	116·5	139	22·5
Oxymethyl-*p*-xylidine. .	OCH_3 CH_3 1 4	86	109	23
Cumidine	CH_3 CH_3 CH_3 1 2 4	98	126	28
Oxymethyl Cumidine . .	OCH_3 CH_3 CH_3 1 2 4	68	96	28

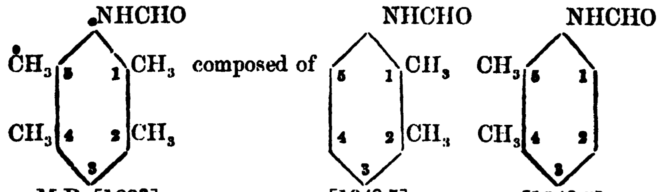
[1] The constitution is expressed as in parts I. and II. on the plan



The tetra-methyl bases exhibit some other peculiarities. As far as the melting-points of their formyl and acetyl derivatives are indications, they would appear to be composed of two xylidines less the melting-point of formo-anilide (46°).

Thus:

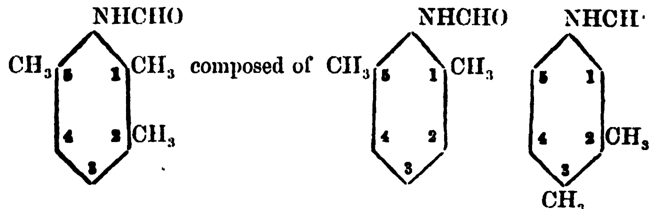
1. Formyl derivative



M.P. [163°] [104°·5] [104°·5]

$$104{\cdot}5 + 104{\cdot}5 - 46 = 163°.$$

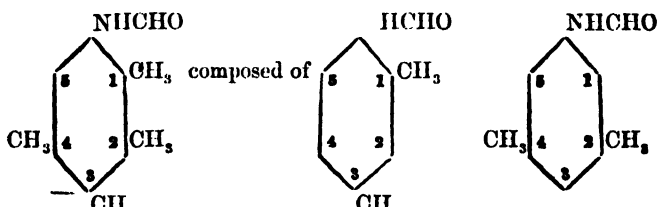
2. Formyl derivative



M.P. [183°] [164°] [65°]

$$164 + 65 - 46 = 183.$$

3. Formyl derivative



M.P. [144°] [113·5] [76·5]

$$113{\cdot}5 + 76{\cdot}5 - 46 = 144.$$

The foregoing are merely a few examples. A much more extended list and an attempt at a discussion of these relations we hope to give shortly.

7. *The Existence of Certain Semicarbazides in more than one Modification.* *By* George Young, *Ph.D.*

In 1887 Michaelis and Schmidt made benzoylphenylsemicarbazide by the ddition of cyanic acid to as-benzoylphenylhydrazine

$$\underset{\displaystyle \mathrm{CO.C_6H_5}}{\mathrm{C_6H_5.N.NH_2}} + \mathrm{HCNO} = \underset{\displaystyle \mathrm{CO.C_6H_5}}{\mathrm{C_6H_5.N.NH.CO.NH_2}}$$

nd found the product to melt at 202–203°. Six years later (1893) Widman btained benzoylphenylsemicarbazide by boiling phenylsemicarbazide, suspended

in benzene, with benzoic chloride, but found the melting-point of the product to be 210–211°.

$$C_6H_5.NH.NH.CO.NH_2 + C_6H_5.COCl = C_6H_5.N(COC_6H_5).NH.CO.NH_2 + HCl.$$

Widman then repeated the preparation, making use of the Michaelis-Schmidt method, and again obtained a product melting at 210–211°. From this it might have been inferred that the lower melting-point obtained by Michaelis and Schmidt was probably due to insufficient purification.

Towards the end of 1896 I had occasion to prepare benzoylphenylsemicarbazide, and made use of Widman's method. The product obtained melted at 202–203°, and the melting-point was not altered by repeated recrystallisations. I had thus obtained the Michaelis-Schmidt product by means of Widman's method of preparation, and at the same time confirmed the Michaelis-Schmidt melting-point. These results having been published in the 'Transactions of the Chemical Society,' Dr. Widman kindly sent to me a sample of his benzoylphenylsemicarbazide, which I found by my thermometer to melt at 210–212°, so that the thermometers were not to blame for the discrepancy.

A comparison of the two substances showed that the one which melted at 202–203° was distinctly more soluble than the higher melting one in the ordinary solvents, such as benzene, ether, alcohol, or water.

The first interesting observation was that on boiling a small quantity of Widman's substance with water: it went into solution very slowly, and on cooling separated in crystals, which melted at about 200°, and, after recrystallisation from dilute alcohol, at 202–203°.

The Widman form of benzoylphenylsemicarbazide had been transformed into the Michaelis-Schmidt form.

The reverse transformation was not so easy, partly because it takes place, even under the best conditions, very slowly; partly because it leads under varying conditions, not only to Widman's benzoylphenylsemicarbazide, but also to a third modification.

This third form of benzoylphenylsemicarbazide melts at 205–206°. It is produced from the lowest melting form by boiling with benzene in a reflux apparatus on the water-bath. The change took place with 2g. substance in about fifteen hours, and further similar treatment was without effect.

This benzoylphenylsemicarbazide, which melts at 205–206°, can be recrystallised unaltered from benzene, ethylic acetate, acetone, or alcohol. Boiling water and, more slowly, dilute alcohol convert it into the lowest melting form.

If the Michaelis-Schmidt product be boiled with benzene in a reflux apparatus on a sand-tray, instead of on a water-bath, the result is different. The change, here again, is slow. After some fifteen hours' boiling the product softens at about 205°, and is completely melted at 210°. Further boiling is without effect. This product can be separated, by washing with cold ethylic acetate, into Widman's benzoylphenylsemicarbazide, which remains undissolved, and the third modification which dissolves in the ester.

By this method of boiling with benzene on a sand-tray the form melting at 205–206° can be converted partially, but never completely, into Widman's modification.

The process of lowering the melting-point from 211–212° to 205–206° is best carried out by boiling with acetone.

The difference in effect produced by exchanging the water-bath for a sand-tray in boiling with benzene suggested what is probably the reason why, although making use of apparently exactly the same method as Dr. Widman in preparing the benzoylphenylsemicarbazide, I obtained, not his product, but that of Michaelis and Schmidt.

In the preparation phenylsemicarbazide and benzoic chloride are boiled in benzene in a reflux apparatus. I had carried out the boiling on a water-bath, and obtained benzoylphenylsemicarbazide of melting-point 202–203°, mixed, as was found later, with a small quantity of the form which melts at 205–206°. On

repeating the preparation in exactly the same manner, with the exception that the water-bath was replaced by a sand-tray, I obtained Widman's results.

These three modifications of benzoylphenylsemicarbazide are not only different in regard to their melting-points and solubilities in various solvents, but they can be distinguished from one another by their appearance under the microscope.

That one of them is not simply a mixture of the other two is shown by the fact that when any two are ground together in a mortar the melting-point of the mixture is no longer sharp, and the two modifications can be separated again by the use of a suitable solvent. A mixture of equal parts of the modifications melting at 205–206° and 211–212° began to soften at 204° and finished melting at 209°; the whole of the lower melting modification could be removed by washing with cold ethylic acetate.

A mixture of equal parts of the modifications melting at 202–203° and 211–212° began to shrink at about 200° and was not entirely melted until 208°. The lower melting substance could be removed by washing with warm benzene.

The property of existing in three such modifications is not confined to benzoylphenylsemicarbazide. I have obtained by similar means, that is, the action of various solvents at different temperatures, three modifications of phenylsemicarbazide, the ordinary form melting at 172°, which in its properties corresponds with the Michaelis-Schmidt benzoyl derivative, and two lower melting forms melting at 164° and 151°, of which the one which melts at 151° corresponds in its insolubility and its stability in benzene with Widman's benzoylphenylsemicarbazide.

o-Tolylsemicarbazide, p-tolylsemicarbazide, and benzoyl-p-tolylsemicarbazide have each been found capable of existence in three modifications, and from indications obtained with other semicarbazides it seems probable this would be the case with all those of the general form $R.R'.NH.NH.CO.NH_2$ where R is a benzenoid radical and R′ is hydrogen or benzoyl.

As to the relation of these modifications to each other, the semicarbazides in question may be trimorphous, or we may have to deal with some form of stereoisomerism. Unfortunately, although we have tried a number of reactions, we have not been able as yet to find one which showed a difference in the chemical behaviour of the three modifications, and we might therefore accept the theory of trimorphism were it not for two facts.

The first is that it is possible to recrystallise two and sometimes all three modifications from the same solvent, and even in presence of one another, without conversion of one into another. That seems to me to dispose of trimorphism.

The second fact is that with certain semicarbazides, diphenylsemicarbazide $(C_6H_5)_2N.H.CO.NH_2$, hydrazodicarbamide $NH_2.CO.NH.NH.CO.NH_2$, and benzalsemicarbazone $C_6H_5.CH.N.NH.CO.NH_2$, I have been unable to obtain even a suggestion of a second form.

That seems to point to the property of existing in these different forms being dependent on the nature of the groups in position 1.

$$\underset{(1)}{NH_2}.\underset{(2)}{NH}.\underset{(3)}{CO}.\underset{(4)}{NH_2}.$$

At present, however, we have not sufficient evidence on which to base any theoretical explanation.

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8. *Report on Isomeric Naphthalene Derivatives.*—See Reports, p. 152.

9. *Report on Isomorphous Derivatives of Benzene.*—See Reports, p. 78.

TUESDAY, SEPTEMBER 17.

The following Papers and Reports were read:—

1. *Some Points in Chemical Education. By* JOJI SAKURAI, *LL.D., Professor of Chemistry in the Imperial University of Tokyo, Japan.*

The marvellous and wonderfully rapid progress which chemistry has made within the last fifteen years is characterised by the fact that not only experimental means of investigation have been extended, enriched, and made accurate, but also a number of comprehensive and fertile ideas have been developed one after another, and deductive methods of inquiry made possible and found to be exceptionally fruitful; chemistry has, in fact, thrown off much of its empirical character, and established itself to be a truly rational science. The educational value, which it has thus acquired, is enormous, a student of modern chemistry having ample opportunities of cultivating the power of observation and the faculty of reasoning at the same time—a two-sided advantage which is possessed neither by an essentially descriptive science nor by an essentially abstract science.

The teaching of chemistry from the point of view attained by the recent development is not only important for those who would become pure chemists, but also for those who would have to apply the knowledge of that science in special directions, such as physiology and chemical technology, inasmuch as its conceptions are exceedingly comprehensive and fertile, their applications in these directions having already led to some important practical results. It is also no less important for the education of boys in secondary schools, as it puts the fundamental facts of chemistry in a clear, intelligent, and rational form, supplying requisite food for the healthy development of their brain.

Notwithstanding these evident and exceptional advantages which the teaching of modern chemistry affords, it is still taught, to a great extent, in the same dry and merely descriptive way as in old days, explanations which are in direct opposition to well-established facts being, moreover, not unfrequently given; and for the interest of our science and profession this state of things should be speedily remedied.

One of the remedies would be to remove certain misconceptions which seem to prevail pretty freely. Now the name 'physical chemistry,' which has come into general use, has apparently given to many an idea that it is a special branch of chemistry, whilst, in fact, it pervades the whole domain of our science and treats of specially important and fundamental chemical questions. Exclusive use of the name 'general chemistry,' in its stead, would have the effect of removing this misconception and of accelerating a more free introduction of modern views into the teaching of chemistry. Another misconception, which seems to have crept into the minds of many, relates to the use of mathematics. It is often stated that, as the treatment of general chemistry requires higher mathematics, it is neither possible nor desirable to introduce it into elementary teaching, but in this opinion there is a confusion of ideas. It is true that, for a detailed study and cultivation of general chemistry, a fair knowledge of higher mathematics is both desirable and necessary. This fact should, indeed, be clearly and generally recognised, and students of chemistry should be encouraged to acquire this knowledge. But the teachings of general chemistry can be introduced into elementary text-books without any mathematics, and yet in a concise, useful, and interesting form; moreover, simple and appropriate lecture experiments, illustrating the laws of chemical dynamics, the theory of solutions, &c., can be easily contrived.

A very effective remedy would be to diffuse the knowledge of, and to increase the interest in, modern views among the teachers in secondary schools. For this purpose courses of lectures, in which general chemistry is amalgamated with descriptive matter, should be given to them, say during summer vacations; also writing of elementary text-books on the same plan should be encouraged.

The objection, which might be raised, that the attempt to give a fair training

in general chemistry over and beyond what it has been customary to teach takes too much time is met by the consideration of the fact that some portion of the descriptive matter usually given in lectures may be cut off, not with inconvenience, but rather with advantage, inasmuch as in the class-room the attention of students should be more directed to points of general interest and importance, whilst the time usually devoted to analytical work in the laboratory may also be conveniently shortened; what the student should learn from it being rather principles and methods of analysis than mere practical skill.

2. *On the Detection and Estimation of Arsenic in Beer and Articles of Food.* *By* W. Thomson, *F.R.S.E.*

3. *On the Nomenclature of the Ions.* *By* Professor James Walker, *F.R.S.*

4. *On the Equilibrium Law as applied to Salt Separation and to the Formation of Oceanic Salt Deposits.* *By* Dr. E. Frankland Armstrong.—See Reports, p. 262.

5. *Report on the Bibliography of Spectroscopy.*—See Reports, p. 155.

WEDNESDAY, SEPTEMBER 18.

The following Papers were read:—

1. *The Electrolytic Conductivity of Halogen Acid Solutions.* *By* Dr. J. Gibson.

2. *On the Flame Coloration and Spectrum of Nickel Compounds.* *By* P. J. Hartog.

It was shown that when nickel acetate is brought into a Bunsen flame together with hydrochloric acid two kinds of coloration may be produced: (1) a temporary purple coloration which flashes out and disappears; (2) a more permanent deep-red coloration. The temporary coloration is so evanescent that the spectrum of bright lines to which it gives rise could not be mapped by the eye. It is hoped to record it photographically. The deep-red coloration gives with a single prism spectroscope two bands—a red band, extending from wave length 6202 to 6126, and a green band, extending from 5328 to 5290. It was shown by spraying a 10 per cent. solution of nickel acetate into a Smithells separator that the coloration is produced in the inner cone. The solution must be either mixed with hydrochloric acid or chloroform vapour must be introduced into the flame in the manner used by Smithells in his researches on flame coloration. Nickel chloride introduced into the flame gives only a slight red coloration. Cobalt acetate was found to yield no flame coloration.

The theory of flame coloration is still obscure, despite the researches of Pringsheim and Smithells; but these experiments lend support to the view that chemical action is necessary for the production of colour in the flame. It was pointed out that in the case of manganese the flame coloration (green) said to be 'sometimes' produced can always be produced with the acetate.

3. *The Methods of Determining the Hydrolytic Dissociation of Salts. By* Dr. R. C. Farmer.—See Reports, p. 240.

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4. *The Influence of Solvents on the Rotation of Optically Active Compounds. By Dr.* T. S. Patterson.

Section C.—GEOLOGY.

President of the Section—John Horne, F.R.S., F.R.S.E., F.G.S.

THURSDAY, SEPTEMBER 11.

The President delivered the following Address:—

Recent Advances in Scottish Geology.

A quarter of a century has elapsed since the British Association met in this great industrial centre, when Professor Young, in his presidential address to this Section, pointed out some of the difficulties which, as a teacher, he experienced in summarising the principles of geology for his students. At that meeting, also, the late Duke of Argyll, whose interest in geological questions never faded, gave an address 'On the Physical Structure of the Highlands in connection with their Geological History.' The return of the Association to the second city of the empire, which since 1876 has undergone remarkable development, due in no small measure to the mineral wealth of the surrounding district, suggests the question, Has Scottish geology made important advances during this interval of time? Have we now more definite knowledge of the geological systems represented in Scotland, of their structural relations, of the principles of mountain-building, of the zonal distribution of organic remains, of the volcanic, plutonic, and metamorphic rocks so largely developed within its borders? It is true that many problems still await solution, but anyone acquainted with the history of geological research must answer these questions without hesitation in the affirmative. In the three great divisions of geological investigation—in stratigraphical geology, in palæontology, in petrology—the progress has indeed been remarkable. The details of these researches are doubtless familiar to many who have taken an active share in the work, but it may serve a useful purpose, and perhaps be helpful as a landmark to give now an outline of some of the permanent advances in the solid geology of Scotland during the last quarter of a century.

The belt of Archæan gneisses and schists, which may be said to form the foundation stones of Scotland, have been mapped in great detail by the Geological Survey since 1883 along the western part of the mainland in the counties of Sutherland and Ross. In that region they occupy a well-defined position, being demonstrably older than the great sedimentary formation of Torridon Sandstone and overlying Cambrian strata. The mapping of this belt by the survey-staff and the detailed study of the rocks both in the field and with the microscope by Mr. Teall have revealed the complexity of the structural relations of these crystalline masses, and have likewise thrown considerable light on their history. These researches indicate that, in the North-west Highlands, the Lewisian (Archæan) gneiss may be resolved into (1) a fundamental complex, composed mainly of gneisses that have affinities with plutonic igneous products, and to a limited extent of crystalline schists which may without doubt be regarded as of sedimentary

origin; (2) a great series of igneous rocks intrusive in the fundamental complex in the form of dykes and sills.[1]

The rocks of the fundamental complex which have affinities with plutonic igneous products occupy the greater part of the tract between Cape Wrath and Skye. Mr. Teall has shown that they are essentially composed of minerals that enter into the composition of peridotites, gabbros, diorites, and granites; as, for example, olivine, hypersthene, augite (including diallage), hornblende, biotite, plagioclase, orthoclase, microcline, and quartz. In 1894 he advanced a classification of these rocks, based mainly on their mineralogical composition and partly on their structure, which has the great merit of being clear, comprehensive, and independent of theoretical views as to the history of the rock masses. Stated broadly, the principle forming the basis of classification of three of the groups is the nature of the dominant ferro-magnesian constituent, viz., pyroxene, hornblende, or biotite, while the members of the fourth group are composed of ferro-magnesian minerals without felspar or quartz.[2] The detailed mapping of the region has shown that these rock-groups have a more or less definite geographical distribution. Hence the belt of Lewisian gneiss has been divided into three districts; the first extending from Cape Wrath to Loch Laxford; the second, from near Scourie to beyond Lochinver, and the third from Gruinard Bay to the island of Raasay. In the central area (Scourie to Lochinver) pyroxene gneisses and ultrabasic rocks (pyroxenites and hornblendites) are specially developed, while the granular hornblende rocks (hornblende gneiss proper) and the biotite gneisses are characteristic of the northern and southern tracts. These are the facts, whatever theory be adopted to explain them.

In those areas where the original structures of the Lewisian gneiss have not been effaced by later mechanical stresses it is possible to trace knots, bands, and lenticles of unfoliated, ultrabasic, and basic rocks to note the imperfect separation of the ferro-magnesian from the quartzo-felspathic constituents, to observe the gradual development of mineral banding and the net-like ramification of acid veins in the massive gneisses. Many of these rocks cannot be appropriately described as gneiss. Indeed, Mr. Teall has called attention to the close analogy between these structures and those of plutonic masses of younger date.

In the Report on Survey Work in the North-west Highlands, published in 1888, the parallel banding, or first foliation, as it was then termed, of these original gneisses was ascribed to mechanical movement.[3] But the paper on 'Banded Structure of Tertiary Gabbros in Skye,' by Sir A. Geikie and Mr. Teall,[4] throws fresh light on this question. In that region the gabbro displays the alternation of acid and basic folia, the crumpling and folding of the bands like the massive gneisses of the Lewisian complex. Obviously in the Skye gabbro the structures cannot be due to subsequent earth movements and deformation. The authors maintain that they are original structures of the molten magma, and, consequently, that much of the mineral banding of the Lewisian gneisses, as distinguished from foliation, may be due to the conditions under which the igneous magma was erupted and consolidated. Whatever theory be adopted to explain the original mineral banding of the Lewisian gneisses, it is certain that they possessed this banding, and were thrown into gentle folds before the uprise of the later intrusive dykes.

The crystalline schists that have affinities with rocks of sedimentary origin occupy limited areas north of Loch Maree and near Gairloch. The prominent members of this series are quartz schists, mica schists, graphitic schists,

[1] Report on the Recent Work of the Geological Survey in the North-west Highlands of Scotland based on the Field-notes and Maps of Messrs. B. N. Peach, J. Horne, W. Gunn, C. T. Clough, L. W. Hinxman, and H. M. Cadell, *Quart. Journ. Geol. Soc.*, vol. xliv. p. 387; and *Annual Report of the Geological Survey* for 1894, p. 280, and 1895, p. 17.

[2] *Annual Report of the Geological Survey* for 1894, p. 280.

[3] *Quart. Journ. Geol. Soc.*, vol. xliv. p. 400.

[4] *Ibid.*, vol. l. p. 645.

limestones and dolomites with tremolite, garnet and epidote.[1] They are there associated with a massive sill of epidiorite and hornblende schist. The relations which these altered sediments bear to the gneisses that have affinities with plutonic igneous products have not been satisfactorily determined. But the detailed mapping has proved that north of Loch Maree they rest on a platform of Lewisian gneiss, and are visibly overlain by gneiss with basic dykes (Meall Riabhach), and that both the gneiss complex and altered sediments have been affected by a common system of folds. In the field, bands of mylonised rock have been traced near the base of the overlying cake of gneiss, and the microscopic examination of the latter by Mr. Teall has revealed cataclastic structures due to dynamic movement. It is obvious, therefore, that, whatever may have been the original relations of the altered sediments to the gneiss complex, these have been obscured by subsequent earth-stresses.

The great series of later igneous rocks which pierce the fundamental complex in the form of dykes and sills is one of the remarkable features in the history of the Lewisian gneiss. In 1895 Mr. Teall advanced a classification of them,[2] but his recent researches show that they are of a much more varied character. For our present purpose we may omit the dykes of peculiar composition and refer to the dominant types. These comprise: (1) ultrabasic rocks (peridotite), (2) basic (dolerite and epidiorite), and (3) acid (granite and pegmatite). The evidence in the field points to the conclusion that the ultrabasic rocks cut the basic, and that the granite dykes were intruded into the gneisses after the eruption of the basic dykes. The greater number of these dykes consists of basic materials. It is important to note that the basic rocks best preserve their normal dyke-like features in the central tract between Scourie and Lochinver, where they traverse the pyroxene gneisses. But southwards and northwards of that tract, in districts where they have been subjected to great dynamic movement, they appear as bands of hornblende schist, which are difficult to separate from the fundamental complex. The acid intrusions are largely developed in the northern tract between Laxford and Durness; indeed, at certain localities in that region the massive and foliated granite and pegmatite are as conspicuous as the biotite gneisses and hornblende gneisses with which they are associated.

After the eruption of the various intrusive dykes the whole area was subjected to enormous terrestrial stresses which profoundly affected the fundamental complex and the dykes which traverse it. These lines of movement traverse the Lewisian plateau in various directions, producing planes of disruption, molecular rearrangement of the minerals and the development of foliation. It seems to be a general law that the new planes of foliation both in the gneiss and dykes are more or less parallel with the planes of movement or disruption. If the latter be vertical or nearly horizontal the inclination of the foliation planes is found to vary accordingly.

Close to the well-defined disruption-planes, like those between Scourie and Kylesku, the gneiss loses its low angle, is thrown into sharp folds, the axes of which are parallel with the planes of movement. The folia are attenuated, there is a molecular rearrangement of the minerals, and the resultant rock is a granulitic gneiss. Indeed, the evidence in the field, which has been confirmed by the microscopic examination of the rocks by Mr. Teall, seems to show that granulitic biotite and hornblende gneisses are characteristic of the zones of secondary shear. A further result of these earth-stresses is the plication of the original gneisses in sharp folds, trending N.W. and S.E. and E. and W.; and the partial or complete recrystallisation of the rocks along the old planes of mineral banding.

In like manner, when the basic dykes are obliquely traversed by lines of disruption, they are deflected, attenuated, and within the shear zones appear frequently as phacoidal masses amid the reconstructed gneiss. These phenomena are accompanied by the recrystallisation of the rock and its metamorphosis into hornblende schist. Similar results are observable when the lines of movement

[1] *Annual Report of the Geological Survey* for 1895, p. 17.
[2] *Ibid.*, p. 18.

are parallel with the course of the dykes. All the stages of change from the massive to the schistose rock can be traced—the replacement of pyroxene by hornblende, the conversion of the felspar and the development of granulitic structure with foliation. Here we have an example of the phenomena developed on a larger scale by the post-Cambrian movements, viz., the production of common planes of schistosity in rocks separated by a vast interval of time, quite irrespective of their original relations. For both gneiss and dykes have common planes of foliation, resulting from earth-stresses in pre-Torridonian time.

It is important to note also that linear foliation is developed in the basic dykes where there has been differential movement of the constituents in folded areas. In the case of the anticline mapped by Mr. Clough, near Poolewe in Ross-shire, he has shown that the linear foliation is parallel with the pitch of the folds. All these phenomena tend to confirm the conclusions arrived at by Mr. Teall, and published in his well-known paper 'On the Metamorphosis of Dolerite into Hornblende Schist.'[1]

The ultrabasic and acid rocks likewise occur in the schistose form, for the peridotites pass into talcose schists and the granite becomes gneissose.

In connection with the development of schistosity in these later intrusive rocks it is interesting to observe that where the basic dykes merge completely into hornblende schist, and seem to become an integral part of the fundamental complex, biotite gneisses and granular hornblende gneisses prevail. Whatever be the explanation, the relationship is suggestive.

The unconformability between the Lewisian gneiss and the overlying Torridon Sandstone, which was noted by Macculloch and confirmed by later observers, must represent a vast lapse of time. When tracing this base-line southwards through the counties of Sutherland and Ross, striking evidence was obtained by the Geological Survey of the denudation of that old land surface. In the mountainous region between Loch Maree and Loch Broom it has been carved into a series of deep narrow valleys with mountains rising to a height of 2,000 feet. In that region it is possible to trace the orientation of that buried mountain chain and the direction of some of the old river courses. This remnant of Archæan topography must be regarded as one of the remarkable features of that interesting region.

In 1893 the various divisions of the Torridon Sandstone, as developed between Cape Wrath and Skye, were tabulated by the Geological Survey, which may here be briefly summarised. They form three groups: a lower, composed of epidotic grits and conglomerates, dark and grey shales with calcareous bands, red sandstones, and grits; a middle, consisting of a great succession of false-bedded grits and sandstones; an upper, comprising chocolate-coloured sandstones, micaceous flags with dark shales and calcareous bands. The total thickness of this great pile of sedimentary deposits must be upwards of 10,000 feet, and if Mr. Clough's estimate of the development of the lower group in Skye be correct, this amount must be considerably increased. Of special interest is the evidence bearing on the stratigraphical variation of the Torridon Sandstone when traced southwards across the counties of Sutherland and Ross. The lower group is not represented in the northern area, but southwards, in Ross-shire, it appears, and between Loch Maree and Sleat varies from 500 to several thousand feet in thickness. These divisions of the Torridon Sandstone are of importance in view of the correlation of certain sediments in Islay with the middle and lower Torridonian groups which there rest unconformably on a platform of Lewisian gneiss.

In continuation of the researches of Dr. Hicks, published in his paper 'On Pre-Cambrian Rocks occurring as Fragments in the Cambrian Conglomerates in Britain,'[2] Mr. Teall has specially investigated the pebbles found in the Torridon Sandstone. The local basement breccias of that formation have doubtless been derived from the platform of Lewisian gneiss on which they rest, but the pebbles found in the coarse arkose tell a different story.[3] He has found that they comprise quartzites showing

[1] *Quart. Journ. Geol. Soc.*, vol. xli. p. 133.
[2] *Geol. Mag.*, 1890, p. 516.
[3] *Annual Report of the Geological Survey* for 1895, p. 20.

contact alteration, black and yellow cherts, jaspers with spherulitic structures which indicate that they have been formed by the silification of liparites of the 'Lea-rock' type and spherulitic felsites that bear a striking resemblance to those of Uriconian age in Shropshire. These interesting relics have been derived from formations which do not now occur anywhere in the western part of the counties of Sutherland and Ross, and they furnish impressive testimony of the denudation of the Archæan plateau in pre-Torridonian time.

These Torridonian sediments, like the sandstones of younger date, contain lines of heavy minerals, such as magnetite, ilmenite, zircon, and rutile.[1] The dominant felspar of the arkose group is microcline, that of the basal group oligoclase. In the calcareous sediments of the upper and lower groups fossils might naturally be expected, but the search so far has not been very successful. Certain phosphatic nodules have been found in dark micaceous shales of the upper group which have been examined by Mr. Teall. From their chemical composition these nodules might be regarded as of organic origin; but he has found that they contain spherical cells with brown-coloured fibres, which appear to be débris of organisms.[2]

Early in last century the Torridonian deposits were referred by Macculloch[3] and Hay Cunningham[4] to the 'Primary Red Sandstone,' and by Murchison,[5] Sedgwick, and Hugh Miller to the Old Red Sandstone. The structural relations of the Torridon Sandstone to the overlying series of quartzites and limestones were first clearly shown by Professor Nicol,[6] who traced the unconformability that separates them for 100 miles across the counties of Sutherland and Ross. When Salter pointed out the Silurian facies of the fossils found in the Durness limestone by Mr. Charles Peach, the Torridonian formation was correlated with the Cambrian rocks of Wales by Murchison.[7] The discovery of the *Olenellus* fauna, indicating the lowest division of the Cambrian system, in the quartzite-limestone series by the Geological Survey in 1891[8] demonstrated the pre-Cambrian age of the Torridon Sandstone. In view of that discovery, which proves the great antiquity of the Torridonian sediments, it is impossible to climb those picturesque mountains in Assynt or Applecross without being impressed with the unaltered character of these deposits. Yet it can be shown that under the influence of post-Cambrian movements they approach the type of crystalline schists.

Before proceeding to the consideration of the Durness series of quartzites and limestones and their relations to the Eastern Schists, brief reference must be made to the controversy between Murchison and Nicol regarding the sequence of the strata.

The detailed mapping of the belt between Eriboll and Skye by the Geological Survey has completely confirmed Nicol's conclusions (1) that the limestone is the highest member of the Durness series; (2) that the so-called 'Upper Quartzite' and 'Upper Limestone' of Murchison's sections are merely the repetition of the lower quartzite and limestone due to faults or folds; (3) that there is no conformable sequence from the quartzites and limestones into the overlying schists and gneiss; (4) that the line of junction is a line of fault indicated by proofs of fracture and contortion of the strata. It is true that in the course of his investigations Nicol's views underwent a process of evolution, and that even in the form in which he ultimately presented them he did not grasp the whole truth. We now know that he was in error when he regarded portions of the Archæan gneiss,

[1] *Annual Report of the Geological Survey* for 1893, p. 263.
[2] *Ibid.*, 1899, p. 185.
[3] *Trans. Geol. Soc.*, ser. 1, vol. ii. p. 450; *The Western Isles of Scotland*, vol. ii. p. 89.
[4] *Transactions of the Highland and Agricultural Society of Scotland*, vol. xiii. (1839).
[5] *Trans. Geol. Soc.*, ser. 2, vol. iii. p. 155.
[6] *Quart. Journ. Geol. Soc.*, vol. xiii. p. 17.
[7] *Ibid.*, vol. xv. p. 353.
[8] *Ibid.*, vol. xlviii. p. 227.

occurring in the displaced masses, as igneous rocks intruded during the earth-movements, and that he failed to realise the evidence bearing on dynamic metamorphism resulting from these movements. But I do not doubt that the verdict of the impartial historian will be that Nicol displayed the qualities of a great stratigraphist in grappling with the tectonics of one of the most complicated mountain chains in Europe.

The period now under review embraces the reopening of that controversy in 1878 by Dr. Hicks, and its close in 1884 after the publication of the 'Report on the Geology of the North-west of Sutherland,' by the Geological Survey.[1] The Survey work has confirmed Professor Bonney's identification of the Lewisian gneiss and Torridon Sandstone in Glen Logan, Kinlochewe,[2] brought into that position by a reversed fault; and Dr. Callaway's conclusions regarding overthrust faulting at Loch Broom, in Assynt and in Glencoul.[3] Special reference must be made to the remarkable series of papers by Professor Lapworth on 'The Secret of the Highlands,' in which he demonstrated the accuracy of Nicol's main conclusions, and pointed out that the stratigraphical phenomena are but the counterpart of those in the Alps, as described by Heim.[4] His researches, moreover, led him to a departure from Professor Nicol's views regarding the age, composition, and mode of formation of the Eastern Schists, for in the paper which he communicated to the Geologists' Association in 1884 he announced that their present foliated and mineralogical characters had been developed by the crust-movements which operated in that region since the time of the Durness quartzites and limestones.[5] Allusion must be made also to his great paper 'On the Discovery of the *Olenellus* Fauna in the Lower Cambrian Rocks of Britain,' in which he not only chronicled the finding of this fauna at the top of the basal quartzite in Shropshire, but suggested the correlation of the Durness quartzites and limestones with the Cambrian rocks elsewhere.[6] That suggestion was strikingly confirmed within three years afterwards by the discovery of the *Olenellus* fauna in Ross-shire.

The detailed mapping of the belt of Cambrian strata has proved the striking uniformity of the rock sequence. There is little variation in the lithological characters or thicknesses of the various zones. Basal quartzites, pipe-rock, Fucoid-beds, Serpulite (*Salterella*) grit, limestone, and dolomite form the invariable sequence, for a distance of a hundred miles, to the west of the line of earth-movements. This feature is also characteristic of the fossiliferous zones, for the sub-zones of the pipe-rock, the *Olenellus* fauna in the Fucoid-beds, and the *Salterella* limestone have been traced from Eriboll to Skye. Owing to the interruption of the sequence by reversed faults or thrusts, the higher fossiliferous limestone zones are never met with between Eriboll and Kishorn, but they occur in Skye, where they were first detected by Sir A. Geikie.[7]

Regarding the palæontological divisions of the system, my colleague, Mr. Peach, concludes 'that the presence of three species of *Olenellus* in the Fucoid-beds and Serpulite-grit of the North-west Highlands, nearly allied to the American form *Olenellus Thomsoni*—the type species of the genus—together with *Hyolithes*, *Salterella*, and other organisms found with it, prove that these beds represent the Georgian terrane of America, which, as shown by Walcott, underlies the *Paradoxides* zone.' Hence he infers that there can be no doubt of the Lower Cambrian age of the beds yielding the Olenellus fauna in the North-west Highlands. Mr. Peach further confirms Salter's opinion as to the American facies of the fossils obtained from the higher fossiliferous zones of the Durness dolomite and limestone. He states that 'the latter fauna is so similar to, if not identical with, that occurring in Newfoundland, Mingan Islands, and Point Levis, beneath strata yielding the

[1] *Nature*, vol. xxxi. p. 29, November 1884.
[2] *Quart. Journ. Geol. Soc.*, vol. xxxvi. p. 93. [3] *Ibid.*, vol. xxxix. p. 416.
[4] *Geol. Mag.*, Dec. 2, vol. x. pp. 120, 193, 337.
[5] *Proc. Geol. Assoc.*, vol. viii. p. 438; *Geol. Mag.*, Dec. 3, vol. ii. 1885, p. 97.
[6] *Geol. Mag.*, Dec. 3, vol. v. pp. 484–487.
[7] *Quart. Journ. Geol. Soc.*, vol. xliv. p. 62.

Phyllograptus fauna of Arenig age, that the beds must be regarded as belonging to the higher divisions of the Cambrian formation.'

The intrusive igneous rocks of the Assynt region, of later date than Cambrian time, and yet older than the post-Cambrian movements, have been specially studied by Mr. Teall, who has obtained results of special importance from a petrological point of view. This petrographical province embraces the plutonic complex of Cnoc na Sroine and Loch Borolan, and the numerous sills and dykes that traverse the Cambrian and Torridonian sediments, and even the underlying platform of Lewisian gneiss. He infers that the plutonic rocks have been formed by the consolidation of alkaline magmas rich in soda. At the one end of the series is the quartz-syenite of Cnoc na Sroine, and at the other the basic augite-syenite, nepheline-syenite, and borolanite. The basic varieties occur on the margin, and the acid varieties in the centre. The sills and dykes comprise two well-marked types, camptonites or vogesites, and felsites with alkali felspar and ægirine, which he believes to represent the dyke form of the magmas that gave rise to the plutonic mass.[1]

The striking feature in the geology of the North-west Highlands is the evidence relating to those terrestrial movements that affected that region in post-Cambrian times, which are without a parallel in Britain. The geological structures produced by these displacements are extremely complicated, but the vast amount of evidence obtained in the course of the survey of that belt clearly proves that, though the sections vary indefinitely along the line of complication, they have certain features in common which throw much light on the tectonics of that mountain chain. Some of these features may thus be briefly summarised.

1. By means of lateral compression or earth-creep the strata are thrown into a series of inverted folds which culminate in reversed faults or thrusts.

2. Without incipient folding, the strata are repeated by a series of minor thrusts or reversed faults which lie at an oblique angle to the major thrust-planes and dip in the direction from which the pressure came, that is, from the east.

3. By means of major thrusts of varying magnitude the following structures are produced: (*a*) the piled up Cambrian strata are driven westwards along planes formed by the underlying undisturbed materials; (*b*) masses of Lewisian gneiss, Torridon Sandstone, and Cambrian rocks are made to override the underlying piled-up strata; (*c*) the Eastern Schists are driven westwards and, in some cases, overlap all major and minor thrusts till they rest directly on the undisturbed Cambrian strata.

When to these features are added the effects of normal faulting and prolonged denudation, it is possible to form some conception of the evolution of those extraordinary structures which are met with in that region. Some of the features just described occur in other mountain chains affected by terrestrial movement, as in the Alps and in Provence; but there is one which appears to be peculiar to the North-west Highlands. It is the remarkable overlap of the Moine Thrust-plane—the most easterly of the great lines of displacement. Along the southern confines of the wild and complicated region of Assynt, that plane can be traced westwards for a distance of six miles to the Knockan cliff, where the micaceous flagstones rest on the Cambrian limestone. In Durness we find an outlier of the Eastern Schists reposing on Cambrian limestone, there preserved by normal faults, at a distance of about ten miles from the mass of similar schists east of Loch Eriboll, with which it was originally continuous.

Though many of these structures appear incredible at first, it is worthy of note that some have been reproduced experimentally by Mr. Cadall.[2] He took layers of sand, loam, clay, and plaster of Paris, and after the materials had set into hard brittle laminæ, in imitation of sedimentary strata, he applied horizontal pressure under varying conditions. The results, some of which may here be given, were remarkable.

[1] *Geol. Mag.*, December 4, vol. vii. p. 385 (1900).
[2] *Trans. Royal Soc. Edinburgh*, vol. xxxv. p. 337.

1. The compressed mass tends to find relief along a series of gently inclined thrust-planes, which dip towards the side from which pressure is exerted.

2. After a certain amount of heaping up along a series of minor thrust-planes, the heaped-up mass tends to rise and ride forward bodily along major thrust-planes.

3. The front portion of a mass being pushed along a thrust-plane tends to bend over and curve under the back portion.

4. A thrust-plane below may pass into an anticline above; and a major thrust-plane above may and probably always does originate in a fold below.

Now these important experiments confirm the conclusion reached by the Geological Survey from a study of the phenomena in the field, viz., that under the influence of horizontal compression or earth-creep the rocks in that region behaved like brittle rigid bodies which snapped across, were piled up and driven westwards in successive slices. But, further, these displacements were accompanied by differential movement of the materials which resulted in the development of new structures. These phenomena culminate along the belt of rocks in immediate association with the Moine Thrust, where the outcrop of that thrust lies to the east of a broad belt of displaced materials. There, Lewisian gneiss, Torridon Sandstone, and Cambrian quartzite are sheared and rolled out, presenting new divisional planes parallel with that of the Moine Thrust. The Lewisian gneiss shades into flaser gneiss and schist, and ultimately passes into a banded rock like a platy schist. The pegmatites show fluxion structure with felspar 'eyes' like that of the rhyolites. At intervals in these zones of highly sheared rocks, phacoidal masses of Lewisian gneiss appear, in which the pre-Torridonian structures are not wholly effaced. The sills of camptonite and felsite intrusive in the Cambrian rocks become schistose and together with the sediments in which they occur appear in a lenticular form. All these mylonised rocks show a characteristic striping on the divisional planes, due to orientation of the constituents in the direction of movement.

Still more important evidence in relation to the question of regional metamorphism is furnished by the Torridon Sandstone. In the case of the basal conglomerate the pebbles have been flattened and elongated, and a fine wavy structure has been developed in the matrix. In the district of Ben More, Assynt planes of schistosity, more or less parallel with the planes of the Ben More Thrust, pass downwards from the Torridon conglomerate into the underlying gneiss. Both have a common foliation irrespective of the unconformability between them. Again, along the great inversion south of Stromeferry, foliation has been developed in the Torridon conglomerate and overlying Lewisian gneiss, parallel to the plane of the Moine Thrust. The Torridon grits and sandstones south of Kinlochewe and between Kishorn and Loch Alsh are similarly affected by the post-Cambrian movements. Mr. Teall has shown that the quartz grains have been drawn out into lenticles and into thin folia that wind round 'eyes' of felspar. A secondary crypto-crystalline material has been produced, sericitic mica appears in the divisional planes, and in some instances biotite is developed. In short, he concludes that in these deformed Torridonian sediments there is an approximation to the crystalline schists of the Moine type. The stratigraphical horizon of these rocks can be clearly proved. The subdivisions of the Torridon Sandstone have been recognised in those displaced masses which lie to the east of the Kishorn Thrust and to the west of the Moine Thrust. It is worthy of note also that in the belt of highly sheared gneiss south of Stromeferry that comes between the Torridonian inversion in the west and the Moine Thrust on the east Mr. Peach has found folded and faulted inliers of the basal division of the Torridon Sandstone that have a striking resemblance to typical Moine schists.

Regarding the age of these post-Cambrian movements, it is obvious that they must be later than the Cambrian limestone and older than the Old Red Sandstone, for the basal conglomerates of the latter rest unconformably on the eastern schists and contain pebbles of basal quartzite, pipe-rock, limestone, and dolomite derived from the Cambrian rocks of the North-west Highlands.

East of the Moine Thrust or great line of displacement extending from Eriboll

to Skye, we enter the wide domain of the metamorphic rocks of the Highlands, a region now under investigation, and which presents difficult problems for solution. Two prominent types of crystalline schists (Caledonian series, Callaway, and Moine schists of the Geological Survey) have been traced over wide areas in the counties of Sutherland, Ross, and Inverness, and across the Great Glen to the northern slopes of the Grampians. Consisting of granulitic quartzose schists and muscovite-biotite schist or gneiss, they appear to be of sedimentary origin, though crystalline. They are associated with recognisable masses of Lewisian gneiss covering many square miles of ground and presenting many of the structures so characteristic of that complex in the undisturbed areas already described. Within the belt of Lewisian gneiss at Glenelg Mr. Clough has mapped a series of rocks presumably of sedimentary origin, including graphitic schists, mica schists, and limestones, but the gneiss with which they are associated possesses granulitic structure like that of the adjoining Moine schists.[1] Further, in the east of Sutherland, and also in the county of Ross, foliated and massive granites appear which are interleaved in the adjoining Moine schists, forming injection gneisses and producing contact metamorphism.[2]

In the Eastern Highlands the Moine series disappears and is replaced by a broad development of schists, admittedly of sedimentary origin, which have been termed the Dalradian series by Sir A. Geikie. Within recent years it has been divided into certain rock-groups which have been traced by the Geological Survey from the counties of Banff and Aberdeen to Kintyre. It has been found that, though highly crystalline in certain areas, they pass along the strike into comparatively unaltered sediments, as proved by Mr. Hill in the neighbourhood of Loch Awe.[3] Before the planes of schistosity were developed in these Dalradian schists they were pierced by sills of basic rock (gabbro and epidiorite) and acid material (granite), both of which must have shared in the movements that affected the schists, as they merge respectively into hornblende schists and foliated granite or biotite gneiss. Both seem to have developed contact metamorphism; indeed, Mr. Barrow[4] contends that the regional metamorphism so prominent in the south-east Highlands is mainly, if not wholly, due to the intrusion of an early granite magma, now exposed at the surface in the form of local bosses of granite and isolated veins of pegmatite.

The age of the Dalradian schists has not been determined. Though there seems to be an apparent order of superposition, in this series it is still uncertain whether that implies the original sequence of deposition. Since Sir A. Geikie applied the term Dalradian to the Eastern Highland schists in 1891,[5] evidence has been obtained[6] that suggests the correlation of certain rocks along the Highland border with the Arenig and younger Silurian strata of the Southern Uplands. Consisting of epidiorite, chlorite schist, radiolarian cherts, black shales, grits, and limestone, they have been traced at intervals from Arran to Kincardineshire. In the latter region Mr. Barrow contends that they are separated by a line of disruption from the Highland schists to the north; but no such discordance has been detected in the Callander district or in Arran. Though these rocks of the Highland border have been much deformed, yet their occurrence in the same order of succession in that region and in the Southern Uplands is presumptive evidence for their correlation.

In view of this evidence it is not improbable that the Dalradian series may contain rock-groups belonging to different geological systems. Indeed, the result of recent Survey work in Islay tends to support this view. For in the south-west

[1] *Summary of Progress of the Geological Survey* for 1897, p. 37.

[2] 'On Foliated Granites and their Relations to the Crystalline Schists in Eastern Sutherland,' *Quart. Journ. Geol. Soc.*, vol. lii. p. 633.

[3] *Annual Report of the Geological Survey* for 1893, p. 265.

[4] 'Intrusion of Muscovite-biotite Gneiss in the South-east Highlands and its accompanying Metamorphism,' *Quart. Journ. Geol. Soc.*, vol. xlix. p. 330.

[5] *Quart. Journ. Geol. Soc.*, vol. xlvii. p. 72.

[6] *Annual Report of the Geological Survey* for 1893, p. 266 for 1895, p. 25; for 1896, p. 27.

part of that island there is a mass of Lewisian gneiss overlaid unconformably by sedimentary strata which have been correlated with the lower and middle divisions of the Torridon Sandstone. Unfortunately the sequence ends here, as both the gneiss and overlying sediments are separated by a line of disruption or thrust-plane from the strata in the eastern part of the island. And yet, notwithstanding this break, the evidence obtained in the latter district is remarkable, whatever theory be adopted to explain it. There the Islay limestone and black slates appear to be covered unconformably by the Islay quartzite containing Annelid tubes and followed in ascending sequence by Fucoidal shales and dolomites, suggestive of the Cambrian succession in Sutherland and Ross. The Islay quartzite passes into Jura, thence to the mainland, and it may eventually prove to be the Perthshire quartzite, while the Islay limestone and black slate are supposed to be the prolongations of the limestone and slate of the Loch Awe series in Argyllshire.[1]

From the foregoing data it will be seen that much uncertainty prevails regarding the age and structural relations of the metamorphic rocks of the Highlands, but the difficulties that here confront the observer are common to all areas affected by regional metamorphism.

A prominent feature in the geology of the Eastern Highlands is the great development of later plutonic rocks chiefly in the form of granite ranging along the Grampian chain from Aberdeenshire to Argyllshire. In connection with one of these masses a remarkable paper appeared in 1892 which in my opinion has profoundly influenced petrological inquiry in Scotland from the light which it threw on the relations of a connected series of petrographical types in a plutonic complex. I refer to the paper on the 'Plutonic Rocks of Garabal Hill and Meall Breac,' by Mr. Teall and Mr. Dakyns.[2]

The authors showed that this plutonic mass comprises granite, tonalite, augite-diorite, picrites, serpentine, and other compounds. Mr. Teall regards the members of this sequence as products of one original magma by a process of differentiation, the peridotites being the oldest rocks, because the minerals of which they are composed are the first to form in a plutonic magma. As the process of consolidation advances, rocks of a varied composition arise, in the order of increasing acidity, viz., diorites, tonalites, and granites. The most acid rock consists of quartz and orthoclase, which may represent the mother liquor after the other constituents had separated out. Mr. Teall concludes that progressive consolidation of one reservoir gives rise to the formation of magmas of increasing acidity, and hence that basic rocks should precede the acid rocks. This theory of magmatic differentiation—so strenuously advocated by Brögger, Vogt, Rosenbusch, Iddings, Teall, and others—was first applied to the interpretation of varied types of plutonic masses in Scotland by Mr. Teall in the paper referred to. Since then he has extended its application to the granite masses in the Silurian tableland of the south of Scotland, which include rocks, ranging from hyperites at the one end to granitite with microcline, and aplite veins at the other.[3] Many of the phenomena presented by the newer granite masses of the Eastern Highlands seem to lend support to this theory. These views, indeed, have permeated the petrological descriptions of the granitic protrusions in the counties of Aberdeen and Argyll which have been given by Messrs. Barrow, Hill, Kynaston, and Craig[4] in recent years.

One of the remarkable advances in Scottish geology during the period under review is the solution of the order of succession and tectonic relations of the Silurian rocks of the south of Scotland by Professor Lapworth. The history of research relating to that tableland, and of all his contributions to the problems

[1] *Summary of Progress* for 1899, p. 66.

[2] *Quart. Journ. Geol. Soc.*, vol. xlviii. p. 104.

[3] *Annual Report of the Geological Survey* for 1896, p. 40; see also 'The Silurian Rocks of Scotland,' *Geological Survey Memoir*, 1899, p. 607.

[4] *Annual Report of the Geological Survey* for 1897, p. 87; for 1898, pp. 25–28; see also paper on 'Kentallenite and its Relations to other Igneous Rocks in Argyllshire,' *Quart. Journ. Geol. Soc.*, vol. lvi. p. 531.

connected with it, has been given in detail in the recent volume of the Geological Survey on that formation. At present it will be sufficient to refer to his three classic papers, which, in my opinion, record one of the great achievements in British geology. The first, on 'The Moffat Series,'[1] demonstrated, by means of the vertical distribution of the graptolites, the order of succession in those fine deposits (black shales and mudstones), which were laid down near the verge of sedimentation, and are now exposed in anticlinal folds in the central belt. The second, on 'The Girvan Succession,'[2] showed how certain graptolite zones of the Moffat shales are interleaved, in the Girvan region, with conglomerates, grits, sandstones, flagstones, mudstones shales, and limestones, charged with all the varied forms of life found in shallow seas or near shore. In the third, on 'The Ballantrae Rocks of the South of Scotland and their Place in the Upland Sequence,'[3] he indicated the distribution and variation of the Moffat terrane (Upper Llandeilo to Upper Llandovery) and of the Gala terrane (Tarannon), which form the greater part of the uplands. He further pointed out how the rocks and the fossils vary across the uplands according to the conditions of deposition. Finally he proved that the complicated tectonics of the Silurian tableland, its endless overfolds, its endoclinal and exoclinal structures, can be unravelled by means of the graptolite zones. These researches disposed of the order of succession based on Barrande's doctrine of Colonies, and established the zonal value of graptolites as an index of stratigraphical horizons. So complete was the zonal method of mapping adopted by Professor Lapworth, and so accurate were his generalisations, that few modifications have been made in his work.

In the course of the re-examination of the Silurian tableland by the Geological Survey some important additions were made to our knowledge of the Silurian system as there developed. Underlying all the sediments of the uplands there is a series of volcanic and plutonic rocks of Arenig age, the largest development of which occurs at Ballantrae in Ayrshire, where their igneous character was recognised by Professor Bonney. But they appear in the cores of numerous anticlines over an area of about 1,500 square miles, forming one of the most extensive volcanic areas of Palæozoic age in the British Isles. These volcanic rocks are overlain by a band of cherts and mudstones, succeeded by black shales yielding Glenkiln graptolites of Upper Llandeilo age. The cherts, which are abundantly charged with Radiolaria, implying oceanic conditions of deposition, are about 70 feet thick, and have been traced over an area of about 2,000 square miles. The deposition of the Radiolarian ooze must have occupied a long lapse of time. Indeed the cherts and mudstones represent the strata which, in other regions, form the Upper Arenig and Lower Llandeilo divisions of the Silurian system. They furnish interesting evidence of the oceanic conditions which here prevailed in early Silurian time, and form a natural sequel to Professor Lapworth's researches bearing on the graptolitic deposits of the Upper Llandeilo period, which must have been laid down on the sea-floor near the limit of the land-derived sediment.

Of special interest is the new fish fauna found by the Geological Survey in the Ludlow and Downtonian rocks between Lesmahagow and Muirkirk, which the researches of Dr. Traquair have shown to be of great biological and palæontological value.[4] This discovery has enabled him to give a new classification of the *Ostracodermi*, to enlarge the order of the *Heterostraci*, which now includes four families, instead of the *Pteraspidæ* alone. He has further shown that the *Cœlolepidæ* were not Cestraciont sharks to which the *Onchus* spines belonged, but *Heterostraci*, though probably of Elasmobranch origin, judging from the shagreen-like scales. The *Cœlolepidæ* are common fishes in the Ludlow and Downtonian rocks of Lanarkshire. The genus, *Thelodus*, first described by Agassiz from detached scales in the Ludlow bone-bed, and subsequently figured and described by Pander and Rohon from scales in the Upper Silurian rocks of Oesel, is here represented for the first time by nearly complete forms. But it is remarkable that no *Onchus* spines, nor any *Pteraspidæ*, nor *Cephalaspidæ* have been found in the

[1] *Quart. Journ. Geol. Soc.*, vol. xxxiv. p. 240. [2] *Ibid.*, vol. xxxviii. p. 537.
[3] *Geol. Mag.*, Dec. 3, vol. vi. p. 20. [4] *Trans. Roy. Soc. Edin.*, vol. xxxix. p. 827.

Lanarkshire strata, the nearest related genus to *Cephalaspis* being *Ateleaspis*, which, however, represents a distinct family.

The group of sandstones, conglomerates, shales, and mudstones that form the passage-beds between the Ludlow rocks and the Lower Old Red Sandstone in Lanarkshire are now regarded as the equivalents of the Downtonian strata in Shropshire, and are linked with the Silurian system. The mudstones of this group, containing the new fish fauna, likewise yield ostracods, phyllocarid crustaceans, and eurypterids—forms which connect these beds with the underlying Ludlow rocks. The band of greywacke-conglomerate, that extends from the Pentland Hills into Ayrshire, composed largely of pebbles derived from the Silurian tableland, is now taken as the base line of the Lower Old Red Sandstone on the south side of the great midland valley of Scotland.

The period under review has been marked by important additions to our knowledge of the Old Red Sandstone formation. In 1878 appeared a valuable monograph by Sir Archibald Geikie on 'The Old Red Sandstone of Western Europe,'[1] by far the most important treatise on this subject since the publication of Hugh Miller's classic work published in 1841. Following up the view maintained by Fleming, Godwin-Austen, and Ramsay, that the deposits of this formation were laid down in lakes or inland seas, he defined the geographical areas of the various basins in the British area, giving to each a local name. He gave an outline of the development of the rocks north of the Grampians, in Caithness, Orkney, and Shetland. He advanced an ingenious argument in favour of correlating the Caithness flagstone series (middle division, Murchison) with the Lower Old Red Sandstone south of the Grampians. He contended that 'the admitted palæontological distinctions between the two areas are probably not greater than the striking lithological differences between the strata would account for, or than the contrast between the ichthyic faunas of adjacent but disconnected water basins at the present time.' Sir A. Geikie further gave a table showing the vertical range of the known fossils of the Caithness series from data partly supplied by the late Mr. C. Peach.

During the last quarter of a century Dr. Traquair has made a special study of the ichthyology of the Old Red Sandstone and Carboniferous strata of Scotland, which has enabled him to throw much light on the distribution of fossil fishes in these rocks and on their value for the purpose of correlation. His researches show that the fish fauna of the formation south of the Grampians resembles that of the Lower Old Red Sandstone of the West of England and adjoining part of Wales in the abundance of specimens of *Cephalaspis*, the common species in Forfarshire (*C. Lyelli*, Ag.) being also indistinguishable from that in the Herefordshire beds. *Pteraspis* occurs in both regions, though of different species. Of Acanthodians *Parexus recurvus*, Ag., occurs in both, together with *Climatius* (*C. ornatus*, Ag.). The abundance of *Cephalaspis* (*C. Campbelltonensis*, Whit., *C. Jexi*, Traq.) and of *Climatius* spines is characteristic of the Lower Devonian rocks of Canada.

The Old Red Sandstone of Lorne has recently yielded organic remains, akin to those found in Forfarshire, south of the Grampians, viz., *Cephalaspis Lornensis* (Traq.), two species of myriapods (*Campecaris Forfarensis* and a species of *Archidesmus*).[2]

In the deposits of Lake Orcadie, north of the Grampians, quite a different fish fauna from that of Forfarshire appears. Dr. Traquair has noted that there are no species common to the two areas, and only two genera, viz., *Mesacanthus* and *Cephalaspis*. The latter genus is, however, represented in Caithness only by a single specimen of a species (*C. magnifica*, Traq.) different from any found elsewhere. It might here be observed that *Cephalaspis* is represented also in the Upper Devonian rocks of Canada by a single specimen of a peculiar species (*C. laticeps*, Traq.), and hence Dr. Traquair has shown that, though *Cephalaspis* is most abundant in the Lower Devonian, it extends also into the upper division of

[1] *Trans. Roy. Soc., Edin.*, vol. xxviii. p. 345.
[2] *Summary of Progress, Geological Survey*, 1897, p. 83.

that system. It further appears that *Osteolepidæ* (*Osteolepis*, *Diplopterus*), *Rhizodontidæ* (*Tristichopterus*, *Gyroptychius*), *Holoptychiidæ* (*Glytolepis*), *Asterolepidæ* (*Pterichthys*, *Microbrachius*), *Ctenodontidæ* (*Dipterus*) are abundant in the Orcadian fauna, none of which has occurred in the Lower Old Red Sandstone of Forfarshire, the West of England, or in the Lower Devonian rocks of Canada. Dr. Traquair recognised, however, the identity of the fishes from the well-known fish band in the basin of the Moray Firth with those brought from the west part of Orkney, though these forms did not quite agree with the fossils from the Thurso district. He subsequently found that the fish fauna from the Orcadian beds in the Moray Firth basin is represented in Caithness by that of Achanarras; and, further, that two other faunas occur in the Caithness area—that of Thurso and that of John o' Groats as given below:—

John o' Groats . . .	*Tristichopterus alatus*, Egert. *Microbrachius Dicki*, Traq.
Thurso	*Coccosteus minor*, H. Miller. *Thursius pholidotus*, Traq. *Osteolepis microlepidotus*, Pander.
Achanarras	*Pterichthys*, 3 species. *Cheirolepis Trailli*, Ag. *Osteolepis macrolepidotus*, Ag.

In 1898 appeared an important paper by Dr. Flett on 'The Old Red Sandstone of the Orkneys,'[1] in which he described the results of his detailed examination of the islands. He proved the existence there of three fish faunas, and their correspondence with those identified in Caithness by Dr. Traquair. From the evidence in the field he adopted the following order of succession and correlation of the strata:—

3. Eday Sandstones and John o' Groats beds.
2. Rousay and Thurso beds.
1. Stromness, Achanarras, and Cromarty beds.

A further important result of Dr. Flett's researches in the Old Red Sandstone of these northern isles was communicated to the Royal Society of Edinburgh this year. He has found in the Shetland beds, which had previously yielded no fossils save plants, fragments, identified by Dr. Traquair as *Holonema*, a fish new to Britain, but occurring in the Chemung group of North America, the subdivision of the Upper Devonian that immediately underlies the Catskill red sandstones, with remains of *Holoptychius*. Dr. Traquair has also recognised in Dr. Flett's collection fragments of *Asterolepis*, a genus characteristic of the Upper Old Red Sandstone, and which, as proved by Dr. Flett, occurs in the 'Thurso beds' of the Orkneys. The interest attaching to this discovery is very great, for Dr. Flett contends that it indicates a fourth life-zone in the Orcadian series, and, further, that it tends to span the break between the Orcadian division and Upper Old Red Sandstone.

In the Upper Old Red Sandstone on the south side of the Moray Firth, Dr. Traquair recognised two life-zones, and subsequently, with the assistance of Mr. Taylor, Lhanbryde, a third; in the following order. The lowest is that of the Nairn sandstones with *Asterolepis maxima* (Ag.); the second, that of Alves and Scaat Craig with *Bothriolepis major* (Ag.), *Psammosteus Taylori* (Traq.); and the highest that of Rosebrae, the fauna of which, according to Dr. Traquair, has a striking resemblance to the assemblage in the Dura Den Sandstones in Fife.

Before 1876 all the Carboniferous areas in the great midland valley of Scotland had been mapped by the Geological Survey. The extent and structural relations of the various coal-fields were determined according to the information then available, and shown in the published maps. But the rapid development of certain fields in the east of Scotland necessitated a revision of them which has lately been done. The Fife coal-field has been re-examined by Sir A. Geikie, Mr. Peach, and

[1] *Trans. Roy. Soc. Edin.*, vol. xxxix. p. 383.

Mr. Wilson, and the oil-shale fields in the Lothians have been mapped by Mr. Cadell. An important memoir by Sir A. Geikie on 'The Geology of Central and Western Fife and Kinross' has just been issued by the Geological Survey, in which the structure of these coal-fields is described. Mr. Cadell lately gave an account of the geological structure of the oil-shale fields in his presidential address to the Edinburgh Geological Society.

Within the period under review detailed researches of great importance on the fossil flora of British Carboniferous rocks have been carried out by Mr. Kidston, to which reference ought to be made. The results are of the highest value for correlating the strata in different areas.[1] By means of the plants he arranges the Carboniferous rocks of Scotland in two great divisions: a lower, comprising the Calciferous Sandstone and Carboniferous Limestone series; and an upper, including the Millstone Grit and the Coal-measures, there being a marked palæontological break at the base of the Millstone Grit. He shows that the upper and lower divisions of the system, not only in Scotland but in Britain, are characterised by a different series of plants, not one species passing from the lower division—save in the case of *Stigmaria*—into the upper. From his researches it appears that, among ferns, *Neuropteris* is all but unknown in the lower division, whereas in the upper it is very abundant. The *Sphenopterids* are proportionately common in both divisions; but those of the lower are usually characterised by cuneate segments, while those of the upper have generally rounded pinnules. *Alethopteris*, so common throughout the whole of the upper series, is entirely absent from the lower. The genus *Calamites*, which is extremely plentiful in the upper, is almost entirely absent from the lower division, where its place is taken by *Asterocalamites*. The *Cordaiteæ* are also rare below the Millstone Grit, though very plentiful above that horizon. *Sigillaria*, so rare in the Lower Carboniferous rocks, is extremely abundant in the upper division, and particularly in the middle Coal-measures. In short, Mr. Kidston concludes that the floras of the two main divisions of the Carboniferous system, though belonging to the same types, are absolutely distinct in species, and in the relative importance of the genera.

By means of the fossil plants Mr. Kidston correlates the Coal-measures of Scotland underlying the red sandstones with the lower division of the Coal-measures of England, and the overlying red sandstones of Fife with the middle division of the English Coal-measures.

It is remarkable that the evidence supplied by the fossil fishes has led Dr. Traquair independently to a similar conclusion. He holds that fossil ichthyology proves the existence of only two great life-zones in the Carboniferous rocks of Central Scotland—an upper and a lower—the boundary line between the two being drawn at the base of the Millstone Grit. The Scottish Carboniferous rocks, being mostly estuarine, give an opportunity of comparing the estuarine fishes of both divisions. He finds the Coal-measure fishes of Scotland to be the same as those in the English Coal-measures, while those occurring below the Millstone Grit in Scotland are mostly different in species, and often, too, in genera, from the forms above that horizon.

Of special interest as bearing on the former extension of this system in Scotland is the discovery made by Professor Judd[2] in 1877 of a patch of Carboniferous sandstones and shales, with well-preserved plant remains in Morven. Another small outlier of this formation has recently been found in the Pass of Brander by the Geological Survey.[3]

The reptiles from the Elgin sandstones, recently described by Mr. E. T. Newton,[4] add fresh interest to the study of these rocks. The structural relations of these sandstones have been fully treated by Professor Judd in his great paper on the Secondary Rocks on the east of Scotland,[5] and again in his presidential address

[1] 'On the Various Divisions of British Carboniferous Rocks as determined by their Fossil Flora,' *Proc. Roy. Phys. Soc. Edin.*, vol. xii. p. 183 (1893).

[2] *Quart. Journ. Geol. Soc.*, vol. xxxiv. p. 685.

[3] *Summary of Progress, Geological Survey*, 1898, p. 129.

[4] *Phil. Trans.*, vol. clxxxiv. p. 431 (1893); *ibid.*, vol. clxxxv. p. 573 (1894).

[5] *Quart. Journ. Geol. Soc.*, vol. xxix. p. 98.

to this Section at Aberdeen,[1] who confirmed Huxley's well-known correlation of these beds with the Trias. The Dicynodont skull, identified by Professor Judd and Dr. Traquair at the Aberdeen meeting of the British Association in 1885, and other remains found in the reptilian sandstones in Cutties Hillock Quarry, where they rest on Upper Old Red Sandstone with *Holoptychius*, have been described by Mr. Newton. He confirmed their affinity with Dicynodonts, though they were referred to the genera *Gordonia* and *Geikia*. But the most remarkable specimen was the skull named by Mr. Newton *Elginia mirabilis*. This extraordinary creature, with a pair of horns projecting like those of a short-horned ox, and with smaller spines and bosses, numbering thirty-nine, is related to the great *Pareiasaurus* from the Karoo beds of South Africa. Two other reptiles are described by Mr. Newton from this quarry, namely, a small crocodile-like animal, *Erpetosuchus Granti*—apparently nearly allied to *Stagonolepis*—and *Ornithosuchus Woodwardi*, which is probably a small Dinosaurian.

Mr. Newton has raised an interesting point in connection with his researches. He calls attention to the fact that the reptilian remains from the Cutties Hillock Quarry differ from those found at other localities in the Elgin district. For example, the Lossiemouth sandstones have yielded *Stagonolepis*, *Hyperodapedon*, and *Telerpeton*; and the Cutties Hillock sandstones, the Dicynodonts (*Gordonia* and *Geikia*), the horned reptile (*Elginia*), the small crocodile-like *Erpetosuchus*, and the little Dinosaurian *Ornithosuchus*. Does this distribution indicate different stratigraphical horizons? is virtually the point raised by Mr. Newton. In connection with this inquiry he cites the evidence obtained in other countries. Thus, in the Gondwana beds of India, the series of reptiles similar to those of Elgin occur at different localities and on different stratigraphical horizons; *Dicynodonts* and *Labyrinthodonts* being found in the lower Panchet rocks, while *Hyperodapedon* and *Parasuchus* (allied to *Stagonolepis*) are met with in the higher Kota-Maleri beds. Again in the Karoo beds of South Africa the *Dicynodonts* and the great *Pareiasaurus*—the latter being the nearest known ally of the horned reptile (*Elginia mirabilis*) from Cutties Hillock, Elgin—occur low down in that formation. Further light is thrown on the question by the interesting discoveries of Amalitzky in Northern Russia, where a number of reptilian remains have been found closely allied to *Pareiasaurus*, *Elginia*, and *Dicynodon*, in beds, which are referred to the Permian formation and accompanied by plants and mollusca which seemingly confirm this reference.[2]

In view of these foreign discoveries Mr. Newton concludes that the Elgin sandstones may probably represent more than one reptilian horizon, and that we are confronted with the possibility of their being of Permian age.

The difficulty of drawing a boundary line between the Trias and the Upper Old Red Sandstone of Elgin, which impressed the mind of the late Dr. Gordon, has had to be faced elsewhere in Scotland. In Arran, my colleague Mr. Gunn has shown that the Trias there rests on the Upper Old Red Sandstone, both formations having a similar inclination. Even he, with his ripe experience, has had great difficulty in drawing a boundary between them on the west side of the island; but when the base line of the Trias is traced eastwards to Brodick it passes transgressively on to Carboniferous rocks.

Of special importance is the recent discovery in Arran of the fossils of the *Avicula contorta* zone[3] by Mr. Macconochie, of the Geological Survey, to whose skill as a fossil collector Scottish geology owes much. With these, occur Lower Liassic fossils, in sediments which are not now found in place in the island. These fossiliferous patches are associated with fragmental volcanic materials filling a great vent, the age of which will be referred to presently. This discovery has fixed the Triassic age of the red sandstones and marls in the south of Arran. The detailed mapping of the island by Mr. Gunn has demonstrated that

[1] *Rep. Brit. Assoc.* for 1885, p. 994.

[2] Y. Amalitzky, *Sur les fouilles de* 1899 *de débris de vertébrés dans les dépôts Permiens de la Russie du nord.* Varsovie, 1900.

[3] *Summary of Progress, Geological Survey*, 1899, p. 133.

the Triassic sandstones rest partly on the Old Red Sandstone, partly on the Carboniferous Limestone Series and partly on the Coal-measures.

In 1878 appeared the third of Professor Judd's great papers on the Secondary Rocks of Scotland, wherein he unravelled the history of these strata as developed in the east of Scotland and in the West Highlands. His admirable researches, in continuation of the work done by Bryce, Tate, and others embraced the identification of the life-zones, their correlation with those of other regions, the history of the physical conditions which prevailed in Scotland during Mesozoic time, and the working out of the structural relations of the strata.[1] He showed that their preservation on the east of Scotland was due to the existence of great faults, and those in the West Highlands to the copious outpouring of the Tertiary lavas. He was the first to detect the occurrence of Cretaceous rocks in the West Highlands and to show the marked unconformability which separates them from the Jurassic strata. His main life-zones and his main conclusions regarding the Secondary Rocks of Scotland have so far been confirmed by the detailed mapping of the Geological Survey. An interesting addition to our knowledge of these rocks was made by my colleague, Mr. Woodward, in the course of his field work, who found the oolitic iron ore in the Middle Lias of Raasay, the position of which corresponds approximately with that of the Cleveland ironstone.[2]

The extensive plateau of Tertiary volcanic rocks in the Inner Hebrides has been a favourite field of research ever since the time of Macculloch, the great pioneer in West Highland geology. During the period under review much work has been done in that domain. According to Professor Judd, that region contains the relics of five great extinct volcanoes and several minor cones, indicating three periods of igneous activity. The first was characterised by the discharge of acid lavas and ashes, the molten material consolidating down below as granite; the second by the outburst of basic lavas, now forming the basaltic plateau, connected with deep-seated masses that appear now as gabbro and dolerite; the third by the appearance of sporadic cones, from which issued minor streams of lava.[3]

In 1888 Sir A. Geikie communicated his elaborate monograph on the history of Tertiary volcanic action in Britain to the Royal Society of Edinburgh,[4] which has been incorporated, with fuller details, in his recent work on 'The Ancient Volcanoes of Great Britain.' His main conclusions may thus be briefly stated: 1. The great basaltic plateaux did not emanate from central volcanoes, but are probably due to fissure eruptions; 2, the basaltic lavas were subsequently pierced by laccolitic masses of gabbro, which produced a certain amount of contact alteration on the previously erupted lavas; 3, the protrusion of masses of granophyre and other acid materials by means of which the basic rocks were disrupted.

During the last six years Mr. Harker has been engaged in mapping the central part of the isle of Skye, and in the petrographical study of the rocks, the results of which have been summarised in the annual reports of the Geological Survey. As regards the basaltic lavas, he finds that while they have been of vast extent the individual flows have been of feeble volume, and show no evident relation to definite centres of eruption. There were two local episodes, however, which took the form of central eruptions: one represented by a number of explosive outbursts at certain points; the other, in the basalt succession, gave rise to rhyolitic rocks.

Mr. Harker further finds that the succeeding plutonic phase of activity, confined in Skye to what is now the central mountain tract, is represented by three groups of plutonic intrusions, in the following order: peridotites, gabbros, and granites. The metamorphism set up in the basaltic lavas near the large plutonic masses presents points of interest, especially the widespread formation of new lime-soda-felspars from the zeolites in the lavas.

After the intrusion of the granite of the Red Hills, Mr. Harker finds that igneous activity took the form of intrusions of smaller volume, but in some cases

[1] *Quart. Journ. Geol. Soc.*, vol. xxix. p. 97, vol. xxxiv. p. 660.
[2] *Geol. Mag.*, Dec. 3, vol. x. p. 493 (1893).
[3] *Quart. Journ. Geol. Soc.*, vol. xxx. p. 220.
[4] *Trans. Roy. Soc. Edin.*, vol. xxxv., part 2, p. 23.

of wide distribution. The great group of dolerite sills belongs to this period. An enormous number of acid and basic dykes followed, of several distinct epochs. A set of minor basic intrusions of quite late date is found in the gabbro district of the Cuillins, the most interesting of which takes the form of sheets of dolerite, parallel at any given locality, but always dipping towards the centre of the gabbro area. Mr. Harker considers that this remarkable system of injections presents a new problem in the mechanics of igneous intrusion. The latest phase of vulcanicity in the Cuillin district is a radial group of peridotite dykes. As regards the local group of rock in Central Skye Mr. Harker finds that the order of increasing acidity which ruled in the plutonic phase was reversed for the minor intrusions which followed.

In connection with the great development of volcanic activity in the West of Scotland in Tertiary time reference must be made to the remarkable volcanic vent in Arran the recognition of which is due to the suggestion of my friend Mr. Peach. This volcanic centre covers an area of about eight square miles, and lies to the south of the granite area of the island.[1] The vent is now filled with volcanic agglomerate and large masses of sedimentary material, some of which have yielded the Rhætic and Lower Lias fossils already referred to, the whole being pierced by acid and basic igneous rocks. One of the interesting features connected with it is the occurrence of fragments of limestone with the agglomerate, which has yielded fossils of the age of the chalk, thus proving that the vent is post-Cretaceous. There is thus strong evidence for referring the granite mass in the north of the island and most of the intrusive, acid, and basic igneous rocks to the Tertiary period. It furnishes remarkable proof of the suggestion of the Tertiary age of the Arran granite made by Sir A. Geikie in 1873.[2] The story unfolded by this discovery is like a geological romance. The former extension of Rhætic and Lower Lias strata and of the chalk in the basin of the Clyde, and the evidence of extensive denudation in the south of Scotland, appeal vividly to the imagination.

This outline of the researches in the solid geology of Scotland would be incomplete without reference to the publication of Sir A. Geikie's great work on 'The Ancient Volcanoes of Great Britain' (1897), in which the history is given of volcanic action in Scotland from the earliest geological periods down to Tertiary time. To investigators it has proved invaluable for reference. Nor can I omit to mention the new edition of his volume on 'The Scenery of Scotland,' wherein he depicts the evolution of the topography of the country with increasing force and fascination. In this domain it may be said of the author, 'Nihil tetigit, quod non ornavit.'

From the brief and imperfect sketch which I have tried to give of recent advances in the solid geology of Scotland it will be admitted that restless activity and progress have been characteristic of the last quarter of a century. But we may expect that the conclusions accepted now will be rigorously tested by our successors, probably in the light of new discoveries and with more perfect methods of research. It is well that it should be so, for thereby our branch of science advances. Meanwhile, as we look back on the phalanx of geologists that Scotland has produced—to Hutton and Hall, Murchison and Lyell, Hugh Miller and Fleming, Nicol and Ramsay—and reflect on the services which they rendered to geology, we may hope that this record of progress may prove a fitting sequel to the labours of these illustrious men.

The following Papers and Report were read:—

1. *Recent Discoveries in Arran Geology.*

By WILLIAM GUNN, *of H.M. Geological Survey of Scotland.*

In the last ten years very important additions have been made to our knowledge of the geology of Arran both in the aqueous and in the igneous rocks of the island.

[1] *Quart. Journ. Geol. Soc.*, vol. lvii. p. 226 (1901).

[2] *Trans. Geol. Soc. Edin.*, vol. ii. p. 305.

Among the older rocks a series of dark schists and cherts has been discovered in North Glen Sannox. They are probably of Arenig age, though no organic remains have been found in them, are closely related to the rocks of Ballantrae in Ayrshire, and similar beds occur in various places along the Highland border where they have been described by Messrs. Barrow and Clough. In the isle of Arran these rocks are intimately connected with the Highland schists.

The Old Red Sandstone of Arran has been found to comprise two subdivisions, and in North Glen Sannox the upper division is unconformable on the lower. This formation is not confined to the ground north of the String road as generally supposed, but extends in places three miles to the south of that road, being well developed in the Clachan Glen, where it is much metamorphosed by intrusive igneous rocks. No fossils have been found in the Old Red Sandstone of Arran except *Psilophyton princeps*, specimens of which have been obtained from the lower division in Glen Shurig.

The Carboniferous formation, fine sections of which occur on the shore at Corrie and at Laggan, is now known to occupy but a small portion of the area of the island. Near Brodick Castle and in Glen Shurig its width of outcrop is not much more than 200 yards, and it does not reach the western shore, being overlapped in the interior by unconformable beds of New Red Sandstone. Beds probably of Coal Measure age with characteristic Upper Carboniferous fossils have been recognised at Sliddery Water Head, Corrie, The Cock, and in various other places, but these have no great thickness and contain no seams of coal. They represent apparently the basement beds of the Coal Measures.

The stratified rocks of the southern part of the island, consisting of red sandstones, conglomerates, and marls, have been proved to repose unconformably on the Carboniferous formation and in places they contain derived pebbles with Carboniferous fossils. All the evidence points to their being of Triassic age, and they may easily be divided into two series, the lower of which probably represents the Bunter sandstone, and the upper the Keuper marls. These Triassic rocks occupy the whole of the coast from Corrie southwards, around the south end of the island, and the west coast up to Machrie Bay, where they appear to lie conformably on the Old Red Sandstone. They also form a small area in the north-eastern part of the island near The Cock.

That still more recent formations once existed in the island, whence they have been removed by denudation, is proved by the presence of fragments of Rhætic, Liassic, and Cretaceous rocks in a large volcanic vent which is probably of Tertiary age. These fragments occur on the western side of the island in the district of Shisken, on the slopes of Ard Bheinn, and they have yielded a considerable number of characteristic fossils which have been examined and determined by Mr. E. T. Newton.

Some of the most important of the discoveries are those connected with the old volcanic rocks of the island.

A series of interbedded lavas and tuffs is found in North Glen Sannox associated with the schists and cherts previously mentioned. Like them they are probably of Arenig age and closely related to similar rocks at Ballantrae in Ayrshire.

Two distinct volcanic platforms have been found in the Old Red Sandstone of the island. One set of basic lavas is intercalated in the lower division on the west side of the island, and another occurs in the upper division of North Glen Sannox.

In addition to the volcanic series previously known in the Lower Carboniferous rocks two others have been discovered in the upper part of the formation.

That the island was the seat of volcanic activity in times still more recent is proved by the recognition of a large volcanic vent in the Shiskin district, which must be of post-Cretaceous age, as shown by some of the fragments it includes.

From these facts we conclude that the island has been the scene of volcanic action at no less than seven different periods.

Much has also been learned with regard to the distribution and age of the various intrusive igneous rocks. Two masses of a somewhat intermediate character found in Glen Rosie and in Glen Sannox are probably of Old Red Sand-

stone age, but nearly the whole of the varied igneous rocks of the island must now be assigned to the Tertiary period, not excepting the well-known granite mass of the northern part of the island. The finer granite which occupies the interior of the nucleus has a tortuous boundary. It is clearly intrusive in the coarse granite which surrounds it, but both belong practically to the same period, as they have one and the same system of jointing.

The ring of granite, granophyre, and quartz diorite which surrounds the large volcanic vent was previously little known, and the other numerous and varied intrusive masses, both acid and basic, which occur in the island were but poorly represented on existing maps.

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2. *On Variation in the Strata in the Eastern Highlands. By* George Barrow, *H.M. Geological Survey.*

[Communicated by permission of the Director of the Geological Survey.]

In mapping the group of rocks associated with the well-known Quartzite and Limestone in the Eastern Highlands, it has been found that there is an incessant variation in the lithological characters of the group, which is sometimes abrupt. Detailed examination has shown that throughout that belt the same type of section or succession reappears after passing a number of variations.

The phenomena are supposed by the author to be due to the strata having been deposited by numerous branches of a large river flowing through a delta. Each branch, by a natural process of fanning, deposits sand near its mouth, and finer mud further seawards. Where the fans of sand are far apart, the fine mud deposited between them will assume a fairly constant composition, because all the streams tap a common source of material before the river divides into branches in the delta.

The recurrence of one particular type of section, which is easily recognised in the field, may be explained by the supposition that the materials of which the strata are composed were laid down as mud or other fine sediment, which may be readily detected by means of the special minerals present, when the rocks are metamorphosed. The abruptness of the changes seen in the sections may be due to the intense folding of the Highland rocks; for materials originally some little distance apart are brought into close proximity, and the transition which once existed is cut out at the surface by the folding.

3. *On the Crystalline Schists of the Southern Highlands. Their Physical Structure and its Probable Manner of Development. By* Peter Macnair.

The area under notice is defined as that lying immediately to the north-west of the great boundary fault which crosses Scotland from the Firth of Clyde to Stonehaven. An account is then given of the various opinions that have been held concerning the structure of this region since the time of Macculloch up to the present day. The author then proceeds to show that the schist zones traverse this region in roughly parallel bands, and described a series of sections at right angles to the strike of the principal foliation of the area. The following is a summary of his conclusions regarding the stratigraphy, physical structure, and the manner of its development in this part of the Scottish Highlands:—

1. The sedimentary schists of the Highlands proceeding from the margin inwards may be divided into the following zones:—Lower Argillaceous zone, Lower Arenaceous zone, Loch Tay Limestone zone, Garnetiferous Schist zone, Upper Argillaceous zone, Upper Arenaceous zone. Associated with these are schists of igneous origin. It is probable that these zones are capable of still further subdivision, but this is not attempted yet.

2. From an examination of the relationships of these different zones, the order

as given above appears to be an ascending one, proceeding from the margin inwards, the well-marked zone known as the Loch Tay Limestone forming a sort of datum line, from which one can recognise the positions of the lower and upper schists.

3. It is supposed that the movements which plicated the rocks of the Highlands were directed from the centre outwards, or from the N.W. towards the S.E. This is shown by the fact that where the bedding can be traced the overfolding is generally towards the S.E. Also the foliation, where it has been folded, faces in the same direction.

4. In the eastern part of the region we suppose that the bedding has been folded into a series of isoclines facing the south-east, and that a foliation has been developed roughly parallel to the axes of the folds in the bedding, thus making the foliation appear to be roughly coincident with the original planes of stratification. At Comrie, in Perthshire, the axes of the isoclines in the bedding are nearly vertical, but with a slight hade towards the N.W. The axes of the isoclines get gradually lower and lower as we proceed towards Loch Tay. In the same way the foliation planes are nearly vertical along the frontier, but get flatter and flatter as we proceed northwards.

5. In tracing these rocks towards the south-west an increasing crumpling and folding of the foliation planes, accompanied by more intense metamorphism, is seen to take place: this is made evident in approaching the shores of Loch Katrine and Loch Lomond, but it seems to have reached its maximum in Cowal.

6. In Cowal, along the Firth of Clyde, the position of the foliation planes has been reversed, now dipping towards the south-east. Between the Firth of Clyde and Loch Fyne the foliation planes have been much crumpled, and still later divisional planes have been developed in them, this being a region of the most intense metamorphism.

4. *The Granite of Tulloch Burn, Ayrshire.*
By Professor JAMES GEIKIE, *F.R.S., and* JOHN S. FLETT, *M.A., D.Sc.*

The granite of Tulloch Burn, Ayrshire, is a small mass occupying an area of three or four square miles on the headwaters of the Irvine and the Avon. Much of the outcrop is covered with drift and peat, but good exposures of the granite and the contact altered rocks can be obtained in the Tulloch Burn, a tributary of the Irvine and on the Avon. The prevalent type is a flesh-coloured biotite-granite, which often contains hornblende and sometimes decomposed augite. This passes at its margins into rocks of intermediate or basic composition, which include various types of diorite, hyperite, and gabbro. The evidence points to the origin of these rocks by a process of differentiation, and both in this respect and in the rock species which have been developed the resemblance to the granites of the Southern Uplands is very close. The material microscopically examined includes:—Graphic Granite and Granophyric Granite (in segregation veins); Biotite Granite, Biotite Hornblende Granite, Biotite Augite Granite; Tonalite (intermediate between Hornblende Biotite Granite and Diorite); Quartz Hornblende Diorite, Quartz Augite Biotite Diorite, Quartz Hypersthene Diorite; Biotite Augite Diorite, Hornblende Diorite, Hypersthene Diorite; Hyperite and Gabbro.

This mass is intrusive into the Lower Old Red Sandstone, which at Lanfine, a little west of this, has yielded Cephalaspis Lyelli. The Old Red Sandstone is indurated and often hornfelsed to a varying distance from the margin. The new minerals developed are Augite, Hornblende, Biotite, Magnetite, Tourmaline, Spinel, and possibly Sillimanite; Calcite, Chlorite, and Epidote are often present, but appear to be secondary after some of those mentioned.

Many dykes penetrate the sandstones, and most of these are undoubtedly apophyses of the Granite. They are mostly Diorite Porphyrites or Quartz Diorite Porphyrites, which may contain Biotite, Augite, Hornblende, or Hypersthene. Syenite Porphyries also occur, and occasionally small veins of more acid character,

which may be considered coarse-grained Granophyres. In addition to these there are several dykes of Olivine Dolerite and Andesitic Basalt, but these are not known to be genetically connected with the Granite.

5. *On Crystals dredged from the Clyde near Helensburgh, with Analyses by* Dr. W. Pollard. *By* J. S. Flett, *M.A., D.Sc.*

6. *Note on a Phosphatic Layer at the Base of the Inferior Oolite in Skye By* Horace B. Woodward, *F.R.S., of the Geological Survey.*

[Communicated by permission of the Director of the Geological Survey.]

At the southern end of the great cliffs of Ben Tianavaig, south of Portree, in Skye, the basement beds of the Inferior Oolite, which contain large dogger-like masses of calcareous sandstone, rest in a hollow of the Upper Lias Shales, owing to local and to a certain extent contemporaneous erosion. Lining this hollow there is an irregular and nodular band, two or three inches thick, of dark brown oolitic and phosphatic rock; a fact of interest, as instances of local erosion are often attended by the accumulation of phosphatic matter in beds, nodules, and derived fossils.

Mr. George Barrow, who made a rough analysis of the rock, estimated the amount of phosphate of lime at about 50 per cent.; and Mr. Teall, who examined a section under the microscope, noted, in addition to the oolite grains, fragments of molluscan shells and echinoderms, and foraminifera, in a finely granular matrix formed of calcite. He observed that the central portions of some of the oolite grains were formed of a nearly isotropic brown substance in which the typical concentric structure of the oolite grains was well preserved. This substance was no doubt phosphatic.

7. *Further Note on the Westleton Beds. By* Horace B. Woodward, *F.R.S.*

In a paper read before the British Association in 1882 (printed in full in 'Geol. Mag.' for 1882, p. 452) evidence was brought forward for regarding the Westleton Beds of Westleton as part of the Middle Glacial division of S. V. Wood, jun. Sections examined during the present year at Pakefield, Kirkley, and Oulton, near Lowestoft, support the author's contention. Thus beneath the Grand Hotel at Kirkley the cliff shows a mass of shingle (identical in character with the Westleton Beds) dovetailing into the undisputed Middle Glacial sands, which a little further south are overlaid by the Chalky Boulder Clay. Evidence of a like character is to be obtained near Halesworth, where the shingle-beds seen south-east of the railway station would be grouped unquestionably with the Westleton Beds, and also (in the author's opinion) with the shingly beds in the Middle Glacial sands east of Oulton station and at Kirkley.

Attention is drawn to sections where a newer gravel is so welded on to the Middle Glacial gravel as to appear in places quite conformable. Similar phenomena observed at the junction of Cretaceous and Eocene clays in Egypt have been aptly referred to by Mr. H. J. L. Beadnell as '*unconformable passage-beds.*'

8. *Report on the Collection and Preservation of Photographs of Geological Interest.*—See Reports, p. 339.

FRIDAY, SEPTEMBER 13.

The following Papers were read:—

1. *Time Intervals in the Volcanic History of the Inner Hebrides. By* Sir ARCHIBALD GEIKIE, *D.C.L., F.R.S.*

2. *The Sequence of the Tertiary Igneous Eruptions in Skye.*[1] *By* ALFRED HARKER, *M.A., F.G.S.*

As regards the sequence of the varied succession of Tertiary igneous eruptions, the isle of Skye may probably be taken as a type of the whole British area. Igneous activity passed successively through three phases: the *volcanic*, the *plutonic*, and the phase of *minor intrusions*. It is important further to recognise two parallel series of events, the *regional* and the *local*; the former of very wide extension, the latter connected with certain definite foci, one of which was situated in Central Skye. The groups of rocks having a regional distribution are all of basic composition, but the local groups exhibit much greater diversity. During the plutonic phase, when regional activity was in abeyance, the successive groups of intrusions at the Skye centre followed an order of increasing acidity (ultrabasic, basic, acid); but for the local groups of the succeeding phase of minor intrusions this order was reversed.

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3. *On the Relations of the Old Red Sandstone of North-west Ireland to the adjacent Metamorphic Rocks, and its similarity to the Torridon Rocks of Sutherland. By* ALEX. MCHENRY *and* JAS. R. KILROE.

The Old Red Sandstone of North-west Ireland has been affected by earth stresses in pre-Carboniferous times, resulting in a system of reverse faults and thrust-planes. This system strikes north north-eastward, and if continued, as is probable, should be represented in the region of Sutherland and Ross. We suggest it is found in the great system of thrusts which affects the structure of the North-west Highlands.

The long-recognised resemblance of the Torridon Rocks in Sutherland to the Old Red Sandstone, especially, as we hold, to the Old Red of Donegal, Tyrone, and Mayo—both as regards its general lithological characters, contained pebbles and relations to the underlying metamorphic rocks, the disposition of the strata, their striking horizontality in places, and strong resemblance of physical features—is fairly suggestive of the contemporaneity of the two groups, a view rendered quite possible by the above-mentioned system of N.N.E. thrust-planes.

Our post-Old Red thrust-planes are in places lined with broken-up débris, in some cases strongly resembling conglomerates of deposition, and giving to the *older* rocks a *pseudo* base, apparently derived from the newer rocks, or newer and older mingled. This, we suggest, may be the case with the base of the Durness series, and the comparatively friable nature of the sandstone and conglomerates would admit of easy movement *en masse* of the lower members of the Durness series in overriding the Torridon when once a thrust-plane became initiated.

4. *On the Relation of the Silurian and Ordovician Rocks of North-west Ireland to the Great Metamorphic Series. By* JAS. R. KILROE *and* ALEX. MCHENRY.

Upper Silurian rocks, as high as Wenlock, have been metamorphosed along the Croagh Patrick range, which led to their inclusion in the great metamorphic

[1] Published in full in the *Geological Magazine*, November 1901, pp. 506–509.

group when the ground was originally mapped. The corresponding rocks of Wenlock age on the south margin of the Mayo and Galway Silurian basin, near Killary Harbour, are not metamorphosed, and rest unconformably upon the metamorphic group.

This stratigraphical break has for many years been supposed to form an insuperable objection to the acceptance of Murchison's conjecture that the metamorphic rocks of Galway, Mayo, &c., are altered representatives of the Lower Silurian or Ordovician rocks. This, however, is not an obstacle, for a break, accompanied by overfolding and possibly metamorphism of Lower Silurian strata, has been proved to have occurred in Llandovery times, which admitted of Wenlock or possibly Tarannon beds being unconformable to unmetamorphosed Lower Silurian, as well as to the metamorphic group. All this happened prior to a second violent disturbance and overfolding which accompanied the metamorphism of Wenlock strata already mentioned, and which occurred in Ludlow times.

A comparison of the Lower Silurian series in the west of Ireland with the metamorphic group of the same region and Donegal shows so strong a resemblance between them—as regards the lithological characters of individual members in their original form, their order of succession, and certain peculiar coincidences of associated sedimentary components, described in detail in the paper—that it forms a creditable *prima facie* argument for their correlation.

One instance may here be mentioned. At Westport and Achill Beg thick bands of fine conglomerate, associated with black slate, occur as an integral part of the metamorphic group, while on the south shore of Clew Bay thick bands of fine conglomerate—very similar in character to those in Achill Beg—occur in association with black slate, which, though sufficiently crushed to justify their inclusion by the original surveyors in the metamorphic ground, are now known to be of Lower Silurian age, identical with rocks of this age in Clare Island.

The chief objection to ascribing the metamorphic rocks of Mayo and Galway to the Lower Silurian age has been the present difference of condition between them and the fossil-bearing Lower Silurians of the adjoining area. This difference seems to us explicable by conceiving that the great dislocation which occurred in Llandovery times, and occasioned an inversion of strata by overfolding at Salrock between the Killaries, carried unmetamorphosed Lower Silurian rocks about Leenane against and over rocks of, say, the same age, near Leenane, which had undergone metamorphism in connection with granitic intrusions. These may be seen in the vicinity of Kylemore. Unfortunately the great zone of break is now concealed by newer strata, and further is obscured and complicated by post-Ludlow faults.

5. *Notes on the Irish Primary Rocks, with their associated Granitic and Metamorphic Rocks. By* G. H. KINAHAN, *M.R.I.A.*

In this communication the writer points out that in previous writings he has insisted that in Ireland there were no Laurentians, because no Irish rocks as a Terrane were similar to the original Laurentians. Now, however, he has learned that the late Dr. G. M. Dawson and other American geologists class the questionable Grenville series, although in part evidently clastic and volcanic, as Laurentian. Consequently, if this is allowed, there are also Laurentians in Ireland and Scotland.

A short review of the American pre-Palæozoic rocks and a table of the classifications adopted in the United States and in the Dominion are given with Dawson's reasons for his objection to the former, as in it the Animikie and Huronian are classed together under one title, Algonkian, although there is a profound break between them. Dawson seems to believe the Animikie and the Keweenawan are more allied to the Palæozoic than to the Archæan: in the latter he would only include the Huronian and the Laurentian.

A table of the Palæozoic rocks, similar to that in the 'Economic Geology of Ireland,' is given and short descriptions of the different strata. This is succeeded by a general description of the different areas of the Irish pre-Palæozoic rocks, more especially those of Donegal and Galway. These two areas are subsequently tabled

as below, and the paper is concluded with a short discussion on the right to call any of the American, Scottish, or Irish rocks the great complex.

In a paper, 'A New Reading of the Donegal Rocks' (see 'Proc. R.D.S.,' vol. vii. (n.s.), part 9, p. 14 *et seq.*) and in the 'Manual of the Geology of Ireland,' lists of the Donegal and Galway and Mayo strata are given: the first we may copy; the second has to be modified to come up to our present knowledge. These lists may be tabulated for comparison.

Donegal.	*Galway and Mayo.*
TERRANE No. I. (Laurentian ?)	(Laurentian ?)
Granitic gneisses, micalitic quartzose gneiss, and subordinate limestone.—This Terrane was invaded by an albitic granite, and it and other granites are solely adjuncts of the area not penetrating the overlying basement great quartzite of the Terrane No. III. *Base not visible.*	Various gneisses, schist in places; zones of hornblendite. Large and long intrudes of hornblende rocks, some excessively developed. These were invaded by the Galway type granite and its accompanying granitic gneiss. *Base not visible.* Over these a profound unconformability.
TERRANE No. II. (Huronians or a new Terrane.)	(Huronians or a newer Terrane.)
1. Gneiss, schists, many hornblendes, with limestone zones, quartzitic gneiss, and garnetiferous limestones. This Terrane was invaded by the typical porphyritic oligoclase Donegal granite with its adjunct the foliated granite or granitic gneiss, latter by other granites, all older than the overlying basement quartzites of Terrane No. III. *Base not exposed.* 2. Gregory Hill schist series, a series of various schists with below them beds of hornblende rocks and one or two limestones. In one place a fine gneiss that seems to be metamorphosed felstone. *Base not exposed.*	The unconformable basement rock is a conglomerate exceedingly altered, various gneisses, schists, and quartzitic gneisses, with a few subordinate limestones. In it are long intrudes of hornblende rock, sometimes tremolite rock, ophite, and elelagite. This Terrane was invaded by the *Omylite granite*, which usually is not accompanied by granitic gneiss, but some of the outlying long intrudes are, and in them is immolated the basement conglomerate. On the rocks of this Terrane are found the basement great quartzites of Terrane No. III.
Profound unconformability.	*Profound unconformability.*
TERRANE No. III. (Keweenawan ?)	
1. The basement strata are the great quartzite with, under it in places, an agglomerate but more often a greenish rock, often quartzitic, in which are scattered widely disseminated rounded pieces of granite and gneiss from the Terrane that may be under it (No. I. or II.). Limestones or dolomites are also found, but only in a few places. The dolomites are associated with the agglomerates, and may be methalosis igneous rocks.	1. The basement stratum is a schistose conglomerate under the great quartzite, with which the conglomerate limestone in places seems to be associated.
2. Cranford limestone, dolomite, and sericitic series.	2. Limestone, ophiolite, dolomite, with schist underneath.
3. Lough Keel or Millford schist series.	3. Quartzite and micalite series.
4. Killygarvan volcanic series.	4. Streamtown limestone and ophiolite series.
5. Killygarvan quartzitic grit series.	5. Micalite series.
6. Lubber volcanic and limestone series.	
7. Barn Hill grit series.	

Donegal.	*Galway and Mayo.*
Profound unconformability. TERRANE No. IV. (Ordovician.)	*Probable unconformability concealed under the Killary and pantry Silurians.*
1. Basement stratum mullaghsawnite, a firm conglomerate, in part arkose.	1. Basement beds unknown.
2. Raphoe limestones and shales.	2. Shales, slates, and grits with, in places, Ordovician fossils.
3. Slates with irregular masses and beds of sandstones, partly arkose. These sandstones, sometimes pebbly, have regular oblique systems of joining. Usually these joints are so close together as to give the rocks the appearance of piles of huge books.	3. Massive grits.
	4. Shales like those in No. 1, but sub-metamorphosed.
	5. Shot conglomerate.
	6. Sandstones with irregular thin beds and pantry of a friable pebbly rock.
	7. Dark slate.

The Lough Keel series, No. 3, Terrane III., is the upper portion of the Millford series, pushed into its present position by an overthrust: it is separated from the Killygarvan volcanic series by a master fault. Between the series 4 and 5, Terrane IV. (Galway and Mayo), there may be an unconformability, and the shot conglomerate may be the equivalent of the mullaghsawnite of the co. Donegal; a break here, however, was not proved. The only series in the Terranes in both columns, the age of which has been proved by their fossils, are those numbered 2, 3, and 4 in the counties Galway and Mayo: these are the equivalents of the Ordovician.

Dawson in his address to the Geological Section at Toronto states his disbelief in the *basement complex*. A. C. Lawson, in his paper 'On Internal Relation and Taxonomy of the Archean of Central Canada' (1890), seems to be of a similar opinion; while Van Hise in his writings only gives a half-hearted consent; the writer finds it hard to believe in it. The section of the Laurentians shown in the cliffs of the Saguenay Fiord is said to be a typical one; and here, between the river St. Lawrence and the Labradorian of St. John, there are various changes—foliated granite, granitic gneiss, felspathic varieties, and quartzitic varieties—that would seem to suggest that the rocks were not one basement complex, but that they had been supplied from zones of distinct magmas as long ago suggested by Delesse. Then we come to the Labradorians of St. John. These in aspect are most ancient, the foliation being extraordinary, so as not to be believed in except seen, some of the measured leaves of quartz and felspar being from 9 to 12 ft. and more long. Yet on examination this rock in its present position is younger than the Laurentians, being intruded and sending apophyses into it: but in its original place it must be older. If the Laurentian is the basement complex, what is the age of the Norian, and what is its genesis? Similarly in Scotland and Ireland. If the Lewisan or fundamental gneiss is Laurentian or basement complex, what is the age of the granites and granitic gneiss with their apophyses? Then there is the 'Old Bay' of Scotland, called hornblende rocks in Ireland: what is its age and genesis? Some, at least, of the Scotsmen say that the Lewisan gneiss is the torn-up 'Old Bay.'[1] If so, how did it exist to be torn up into the *basement complex*? Then there are the quartzitic and highly felspathic varieties of the Lewisan that are said to have their origin in masses of those classes of rocks. These are complications that some people may understand, but others do not see their way to believe that FUNDAMENTAL ROCKS HAD THEIR ORIGIN IN PREFUNDAMENTAL ANCESTORS.

[1] There is a vein of humour in this Scotch sobriquet. The rock is the 'Old Bay,' and yet it is to be torn up for the making of the oldest rocks on the face of creation.

6. *Some Irish Laccolithic Hills.* *By* G. H. Kinahan, *M.R.I.A.*

The author begins by pointing out that laccoliths are not usually classed among the elevators of hills. Of late years Professors Gilbert and Cross, of the U.S.A. Survey—although not the pioneers—have brought this prominently forward. A short list of writers on the subject is given. The south-east of Ireland—Wicklow, Wexford, and Waterford—is mentioned as the portion of the country in which they are conspicuous. Most of those in Wicklow and Wexford were carefully mapped and described.

Gilbert's definition of a laccolith, copied from a letter, is given. It partially differs from his original, as in this he points out that fragments torn from the conduit-pipe are usually found in the laccolith. This statement was made in a reply to a query of the writer, who in his description of the laccoliths of South-east Ireland had specially mentioned them.

A few very characteristic laccoliths are particularly mentioned, such as the range of the Wicklow and Wexford granite hills, this line of upheavals being explained by diagrams illustrating that the granite had come up in pipes through the undermost Oldhamians (Archæan) and lifted up the superior then horizontal Ordovicians; so that now, as a general rule, the Ordovicians, not the Oldhamians, are in contact with the granite. A few remarkable laccolithic hills in other parts of Ireland are also mentioned.

7. *The Geological Distribution of Fishes in the Carboniferous Rocks of Scotland.* *By* Dr. R. H. Traquair, *F.R.S.*

8. *The Geological Distribution of Fishes in the Old Red Sandstone of Scotland.* *By* Dr. R. H. Traquair, *F.R.S.*

9. *Perim Island and its Relations to the Area of the Red Sea.* *By* Catherine A. Raisin, *D.Sc.*

This paper describes briefly rock specimens from Perim Island collected and placed at the disposal of the authoress by Mr. J. A. Rupert Jones (sub-lieutenant R.N.R.), now stationed at Aden.

The island, as shown in the Admiralty chart, has somewhat of a horse-shoe shape, enclosing a harbour opening to the south. Low plains, less than 12 feet above sea-level, extend in from the coast, especially at the north, and consist of raised beaches, but most of the southern and eastern parts are hilly, reaching 249 feet at the highest point.

The specimens received are all from volcanic rocks. The surface, according to Mr. Rupert Jones, is composed mostly, to a depth of about 7 feet, of loose blocks (4 feet or less in diameter), often imbedded in calcareous sand or mud. The underlying rock is exposed in cliffs and in quarries, and occurs generally in roughly horizontal layers. One mass *in situ* (near Balfe Point) is a not very basic basalt (almost an andesite) crowded with felspar microliths with marked fluidal orientation, and is probably a lava flow. Another reddish rock with scattered rounded vesicles (from a cliff north-east of the harbour) approaches a microcrystalline basalt in character, and consists of much plagioclase, clear gum-like augite, some red brown ferruginous olivine or pyroxene, and a little black speckled glassy base. In another spot (near Balfe Point) a whitish tuff or fine agglomerate is quarried, and consists largely of fragments of pumice with some broken felspar, augite, and other crystals.

The surface blocks in one or two examples consist of fragmental rocks. One is a red more basic tuff, containing thin black streaks, apparently of a spherulitic glass. The blocks, however, are mostly scoriaceous and vesicular, petrologically

generally basaltic, and similar to the underlying rocks described above, but with some variation, as if they might represent a broken lava crust. They are crossed by veins of calcite, and the ashy materials and other fragments are often cemented by calcareous deposits.

The history of Perim Island belongs mainly to the Tertiary era. We may infer that the Red Sea, from its general contours and the steep descent of the bed towards a central depression, forms part of the Great Rift Valley, extending from Lake Tanganyika to the Jordan, along which at so many places volcanic outbursts on a large scale have occurred. Both in Arabia and in Abyssinia extensive tracts of volcanic rocks are found of more than one period. The rocks of Perim belong probably to the later or so-called Aden group. The raised beaches of the island are an evidence of oscillations of level, which are proved by upraised and submerged coral reefs to have affected other parts of the Red Sea. Denudation and weathering of the surface took place, and calcareous sediment was deposited, while at different times coral reefs became established in the adjacent shallow seas.

10. *Artesian Water in the State of Queensland, Australia.* *By* R. Logan Jack, *LL.D., F.G.S.*

The western interior of Queensland is endowed with rich grasses, but has an insufficient rainfall. This defect, however, has been to some extent compensated by the success in boring for artesian water, which was commenced in 1885. It is estimated that artesian or sub-artesian water is to be found beneath an area of over 264600 square miles.

The greater part of the western interior of Queensland is composed of soft strata of Lower Cretaceous age, consisting of clay-shales, limestones, and sandstones. These strata are so disposed that the lower members of the series crop out on the western flanks of the coast range, where not only is the elevation of the surface greater than in the downs to the west, but the rainfall is also comparatively abundant.

Along the eastern margin of the Cretaceous area there is a porous sandstone of great thickness, the 'Blythesdale Braystone,' and owing to the low dip the outcrop of this permeable stratum occupies a belt from five to twenty-five miles wide; but the Braystone finally disappears beneath the argillaceous and calcareous upper members of the series which forms the surface of the downs to the west. Several rivers disappear while crossing the outcrop of the Braystone, and the water must be carried in it beneath the clay-shales of the pastoral downs.

It is believed that the subterranean water leaks into the Great Australian Bight between the 124th and 134th meridians of east longitude, and perhaps partly into the Gulf of Carpentaria, as the pressures in the wells decrease with their distance from the elevated outcrop of the Braystone. Mr. J. B. Henderson, hydraulic engineer, has constructed a map showing lines of equal pressure, which enable intending borers to judge whether or not, when they strike water, it will rise to the surface.

The following statistics are from Mr. Henderson's report for the year ending June 30, 1900:—

Aggregate depth of bores	185 miles.
Number of bores	839.
Number of flowing bores	515.
Deepest bore	5040 feet.
Highest temperature	196° F.
Largest flow of a single bore	6000000 gallons per day.
Total output of the 515 flowing bores	117403574585 gallons per annum.

The 515 wells would fill a canal 100 feet wide and 20 feet deep, 1779 miles long, in twelve months; or fill Loch Katrine in a year and a half.

MONDAY, SEPTEMBER 16.

The following Papers and Reports were read:—

1. *The Cambrian Fossils of the North-west Highlands.* *By* B. N. PEACH, *F.R.S.*

[Communicated by permission of the Director of the Geological Survey.]

The Cambrian rocks of the north-west of Scotland occur within a narrow belt of country, less than ten miles wide, stretching from Durness and Eireboll to Skye, a distance of 120 miles.

The lowest member consists of quartzite 500 feet thick, the under half of which is false bedded and devoid of organic remains, and the upper part of which is finer grained and more evenly bedded and pierced by worm pipes, '*Scolithus linearis*,' by means of different forms of which it can be divided up into five sub-zones. The succeeding 'fucoid beds,' consisting of fifty to eighty feet of green mudstones, dolomites, &c., have yielded three species of Olenellus, nearly allied to *Olenellus Thomsoni*. The serpulite grit, from ten to thirty feet thick, usually crowded with Salterellas, has also yielded a species of Olenellus. It is overlaid by a vast column of dolomite, limestone, and subsidiary beds of chert, amounting in all to 1,200 or 1,500 feet in thickness. The first thirty feet of the limestone has yielded two species of Salterella, and the beds up to that point are looked upon as the equivalents of the Olenellus or Georgian Terrane of North America, the whole facies of the fauna being exceedingly like that of America.

The overlying column of dolomite, &c., has been divided into seven sub-zones, varying in thickness from 100 to 400 feet, the three uppermost zones of which have yielded a fauna almost identical with that described by Billings and others from rocks which in Newfoundland and the St. Lawrence region of Canada underlie black shales at Cow Head and Point Levis, yielding a long suite of graptolites characteristic of the *Phyllograptus* or Arenig zone. The Durness dolomite must therefore represent the Middle and Upper Cambrian horizons, and perhaps the base of the Arenig of America and Europe.

As regards the conditions under which these deposits were laid down, the author considers that the basal quartzites show proximity to a low shelving shore line continuous across what is now the Atlantic to America, more or less parallel to the shores of what is now Western Scotland, and a little to the north of the present area; that owing to more or less continuous depression of the area, the 'pipe rock' was deported further from shore, the 'fucoid beds' representing the period when the 'mud line' or limit of sedimentation was reached, while the vast pile of the Durness dolomite represents the débris of the 'Plankton' that fell on the bottom of a clear though not necessarily a deep ocean. Solution of great part of the calcareous ooze while exposed to the action of sea water, and perhaps substitution of magnesian salts for calcareous ones, changed the calcareous oozes into dolomites, while the chert beds represent the reassorted remains of the silicious organisms.

The author pointed out that in Arenig times the sea over what is now the northern part of the southern uplands of Scotland was also a clear one, free from terrigenous sediments, and in which a radiolarian deposit accumulated. If the rocks along the Highland border described by Messrs. Barrow, Clough, and Gunn be the northern continuation of these southern upland rocks, then it is rendered highly probable that in late Cambrian and early Silurian times a clear sea lay across what are now the Highlands of Scotland, which was probably the barrier which divided the Cambrian faunas of America and North-west Scotland on the one side from those of Wales, Bohemia, and the Baltic region of Europe on the other.

2. *The Investigation of Fossil Remains by Serial Sections.* *By* Professor W. J. Sollas, *D.Sc.*, *F.R.S.*

It is now becoming increasingly recognised that the key to the evolution of the animal kingdom is not the exclusive possession of ontogeny alone, but is shared at least equally by the sister science palæontology. The information afforded by the latter study is far less than might be justly expected, owing to the insufficiency of its methods. The method of fossil sections has worked a revolution in zoology since its first introduction some few decades ago. Could it be applied to fossils no less far-reaching results would naturally follow in palæontology. Serial thin sections for examination by transmitted light are, however, in most cases out of the question, since they cannot be obtained in a sufficiently close succession. The same objection, however, does not apply to polished surfaces intended for observation under the microscope by reflected light.

These can be obtained to almost any desired degree of proximity, and a grinding machine designed for the author by the Rev. Gervase Smith, and constructed with the aid of a grant from the Royal Society, furnishes a series of parallel plane surfaces at regular intervals of from 0·1 to 0·03 mm. In the case of fairly well preserved specimens these may be studied under powers of from 1 inch to $\frac{1}{3}$ inch, and all the details of their anatomy ascertained.

Drawings under the camera lucida or photographs may be obtained from them, and from a series of such drawings the fossil may be reconstructed on an enlarged scale. Already several species of fossils have been treated in this way with complete success. Supplemented by a few thin transparent sections it affords a means for ascertaining the anatomy of fossils in fulness and with precision.

The so-called *Ophiura Egertoni*, which the author has studied in conjunction with Miss F. Wright, displays under the method of grinding all those minute characters on which zoologists depend for the determination of recent species, including the tentacle scales, teeth, buccal papillæ, and the granulations on the buccal plates. The details of the anatomy of *Lapworthura Miltoni* are also clearly revealed, and in both cases the anatomy of the jaws is so exactly indicated that from these fossil remains alone the homology of these organs can be ascertained.

Models were exhibited prepared from serial sections of *Palæospondylus Gunni*, Traquair, taken in longitudinal, transverse, and facial directions. These were obtained and studied by Miss Igerna Sollas and the author. They appear to reveal the existence of a dorsal shield, a maxillary arch, a palatine element, and a suspensorium, as well as gill arches. A lower jaw is indicated. While pointing in some directions to the Cyclostomes the more important characters of the fossil suggest affinities with the Amphibia and Dipnoi.

Models in wax have also been prepared of *Monograptus priodon*, and were exhibited before the Section.

3. *Notes on some Fossil Plants from Berwickshire.* *By* R. Kidston.

4. *Report on Life-zones in the British Carboniferous Rocks.* See Reports, p. 288.

5. *Geology regarded in its Economic Application to Agriculture by Means of Soil Maps.* *By* J. R. Kilroe.

It is proposed to consider the means by which geological information can best be applied to agriculture, the utility of the application being assumed to be universally admitted.

Amongst the objects to be aimed at should be the furnishing of reasons and suggestions for the profitable localisation of certain branches of the industry, viz.,

Stock-breeding, Dairying, and Tillage, the last viewed in detail as regards the most economical and profitable application of manures, and the selection of soils most appropriate to different kinds of crops.

Viewed in a more general way, the utility of Geology may be considered, as regards the valuation of land, the development of estates, and schemes of irrigation and drainage.

We may omit the special case in which soils may be regarded as mere receptacles of manures (in places within easy reach of ready markets, in which case high profits are often realised); and proceed to note that in general farming, not only have facilities for drainage and percolation to be considered, as well as the conditions of retentiveness, capillarity, and absorptiveness, or the quality of retentiveness for fertilisers—all of which are determined by geological circumstances—but the nature and abundance or scarcity of crude fertilising substances naturally present in soils, to be operated on and rendered available for plant use by acidulated waters in the ground, have a very important bearing upon the quality of land, and are equally determined by geological considerations.

In virtue of differences in the amounts of the leading fertilising constituents in soils, and differences in the degree of facility with which they are rendered available, a great range of intrinsic soil-values is observable in Ireland, where according to Sir R. Griffith some land is to be met with capable of putting upwards of 3 cwt. of flesh per Irish acre (or 2½ cwt. per statute acre) upon grass-fed animals each season.

Chemical analyses of soils, as means of discriminating as to their resources or deficiencies, of determining the amounts of fertilisers immediately available according to Dr. Dyer's method, or the amounts soluble in aqua regia according to that adopted by M. de Gasparin, or the bulk amounts present in any sample, can never, on account of the expense and number which would be requisite, come to be regarded as a practicable feature of economic farming procedure, unless indeed analyses be applied in connection with some ready and fairly reliable means of comparing soil with soil in different localities. Such means would be afforded by soil maps upon a geological basis.

Agricultural maps (*cartes agronomiques*) have been advocated by such authorities as De Caumont and Delesse on the Continent. Risler, head of the first Agricultural College of France, not only values the aid which geology supplies, but considers that detailed geological maps would suffice for agricultural purposes, such maps in that country fairly suggesting, not only the character of soils resulting from the decay of immediately underlying strata, as regards their physical qualities, whether as sand, loam, clay, and intermediate varieties, but the degree and nature of their endowment also, with fertilising substances.

In the British Isles north of the Thames, Drifts supervene to a great extent, masking or obliterating the characters proper to soils, which otherwise would cover each formation or igneous mass. Hence ordinary geological maps do not here suffice for agricultural purposes in these countries.

The Drift maps published by the Geological Survey, so highly serviceable economically; in thickly populated areas, for purposes of drainage, water supply on a small scale, and in connection with the brick-making industry, seem to me to come short of agricultural requirements in this, that they do not give prominence to information bearing upon the natural endowments of soils as regards fertilisers —not even as much so as ordinary maps showing the solid geology.

I should therefore propose a scheme of soil maps which, while keeping in view the elements upon which the physical qualities of soils depend, gives prominence to information bearing upon the soil resources.

To do this I should use, somewhat as on our original Irish drifted maps, close, wide, and medium stippling, to distinguish sands and gravels, boulder clay, and intermediate varieties respectively—the boundaries of which in the field are exceedingly ill-defined in many places. Over this I should apply a light wash of colour appropriate to one of the following groups of rocks, to represent the soil, whether drift-soil or soil directly formed over rock, according to the prevailing character of débris present in the uppermost layer, the soil and subsoil, reserving

the darker tints of colour for the places where the rock is actually to be seen. Other details are described in the paper.

I should arrange strata and igneous masses in much fewer groups than those represented on geological maps, and retain the system of colours on these maps in so far as they prove ordinarily suggestive of the rocks referred to, viz.—

Limestone (Chalk, &c.)	Blue.
Sandstone and Shale	Slate colour.
Grits and Slate	,, ,,
Quartzite and Schist	,, ,,
Coal Measures	Dark grey.
Basic Rocks	Burnt carmine.
Acid Rocks	Carmine.
Peat Bogs	Sepia.
Gravelly and Coarse Pebbly Alluvial deposits .	Burnt sienna.
Loamy and Peaty Alluvium	Green.

Such a system would tend to meet the strong prejudice existing in farmers' minds against geological technicalities, while keeping the essential points of information concerning soils in the forefront.

The addition of contour lines, even if only approximately drawn from the levels given on the Ordnance maps, would be a valuable addition to these industrial maps in consideration of difference of climatic conditions attendant upon differences of elevation.

6. *Plants and Coleoptera from a Deposit of Pleistocene Age at Wolvercote, Oxfordshire. By* A. M. Bell, *M.A., F.G.S.*

Plant remains of Pleistocene time are of great rarity in England. The two most important series which have been described are from Hoxne, in Suffolk, obtained by Mr. Clement Reid, F.R.S., and Mr. H. N. Ridley ('Geol. Mag.,' 1888, p. 441), and from North London by Mr. Worthington G. Smith.

There is in these remains a singular difference. Of twenty-eight plants obtained at Hoxne three are arctic (Salix polaris, S. myrsinites, Betula nana); seventeen range to the Arctic Circle.

At Stoke Newington, on the contrary, Mr. W. J. Smith obtained the elm, the chestnut, clematis, and perhaps the vine. Only three out of eleven plants reach the Arctic Circle. The pine, the alder, birch, and yew, with the royal fern, were more in harmony with the present and the past floras.

In the author's opinion the Stoke Newington flora represents a much later age of Pleistocene time than the Hoxne flora. The conditions were continental, and the flora of the south was gaining, while the arctic flora was disappearing.

The plants as yet identified, by the kindness of Mr. Clement Reid, from Wolvercote resemble those found at Stoke Newington more than those of Hoxne. This is in harmony with the writer's view that the Wolvercote deposit is of late Pleistocene age, nearer to the Stoke Newington than to the Hoxne deposit.

Eighteen plants obtained by the author are given. All of them are found in Oxfordshire to-day. Eight only have an extension to the Arctic Circle. Four mosses have been obtained, one of which is certainly recent. A considerable number of the wing-cases of beetles have also been found. These are difficult to identify, but the genus of one, remarkable by its rows of hairs, has been named by Mr. Waterhouse, of the Natural History Department of the British Museum. Only one of the genus now is found in England, and that is different from the Wolvercote species. On the other hand the genus is common on the Continent.

These facts, coupled with those from Stoke Newington, tend to the conclusion that in late Pleistocene time the climate of the Thames Valley was more continental than it is at present.

7. *Report on the Terrestrial Surface Waves and Wave-like Surfaces.*

See Reports, p. 398.

8. *Report on the Exploration of Keish Caves, Co. Sligo.*

See Reports, p. 282.

9. *Evidences of Ancient Glacier-dammed Lakes in the Cheviots.* *By* PERCY F. KENDALL, *F.G.S.*, *and* HERBERT B. MUFF, *B.A.*, *F.G.S.*

It is uncertain whether the Cheviot itself was overridden by extraneous ice, but striæ on Thirl Moor and Baker Crag recorded by the Geological Survey probably indicate that this portion of the watershed was overridden by ice from the Tweed Valley, and Prof. Geikie mentions till and striated stones on the tops of the Cheviot Hills at 1,500 ft. The transport of erratics shows movement along both sides of the axis of the range from S.W. to N.E. at some stage of the glaciation. Across the northern end and for at least ten miles down the eastern side, however, a distribution of rocks from the Tweed Valley, together with other indications to be mentioned, points to an ice-flow veering round through easterly to a due north-to-south direction. The observations of the authors go to confirm the above conclusions with respect to the area N. and E. of Cheviot.

The authors, during a few days spent in the district, observed certain features which throw much light on the later stages of the Ice Age in this area. Mr. Clough mentions [1] 'dry, steep-sided little valleys crossing over watersheds, which do not appear to lie along lines of weakness or the outcrops of soft beds. It is suggested that they might have been formed by streams from glaciers.' Some of the valleys observed by us run along the sides of hills or occur as loops detaching portions of the walls of valleys, and the general characters of similar valleys have been described by us separately.[2] Their mode of occurrence and the relations to the relief of the country, as well as to the position occupied by the ancient ice-sheets, show that they can be ascribed only to the overflow of water from lakelets held up by an ice-barrier. In the tract of country between Yeavering Bell and Ingram we found that each of the spurs separating the valleys which radiate from Cheviot was cut across by one or more sharp gorge-like channels, draining, with one significant exception, to the south. The spur between Roddam Dean and the Breamish River is cut near Calder Farm by a channel, bounded on the east by the moraine, draining to the south; but a higher portion of the same spur is traversed by a channel draining in the opposite direction, *i.e.*, to the north. The highest member of a series across any given spur is usually just above the boundary of the drift containing extraneous boulders. At the outlets of the valleys there are, in several cases, deltas represented by masses of gravel.

Conclusions.—The existence of the series of overflow channels points clearly to the former presence of a chain of small lakes held in the radial system of valleys of the Cheviots by a barrier of ice. The ice-stream by the boulders which it bore may be inferred to have swept round the end of the Cheviots out of the Tweed Valley. The margin of the sheet at its maximum extension rose to about 1,000 ft. along the arc from Yeavering Bell to Brand's Hill, beyond which it may have declined. Along the south-eastern slopes of the Cheviots another extraneous glacier swept in a north-east direction. Where their confluence took place, or whether they were not in succession rather than simultaneous, is not easy to decide, but the Roddam Burn channel points very clearly to the preponderating influence of the southern stream, while the Calder Farm overflow lower down the same ridge shows by its southerly slope that the northern ice later acquired the mastery. If the two glaciers were confluent, then the overflowing

[1] *Geol. Surv. Mem.*, 'The Geology of the Cheviot Hills.'

[2] *B.A. Report*, 1899, P. F. Kendall, 'On Extramorainic Drainage in East Yorkshire'; *ibid.*, 1900, A. Jowett and H. B. Muff, 'Preliminary Note on the Glaciation of the Bradford and Keighley District.'

waters of the lakes must have been discharged either beneath the ice, as at present happens to the overflow from a chain of ice-dammed lakes on the Malaspina Glacier, or over the top of the ice.

An important and unexpected result of our brief examination has been the discovery that while 'foreign' ice was rising along the flanks of the Cheviots to an altitude of 1,000 ft., not only were the spurs free from any native ice-sheet, such as Cheviot or Hedgehope might have been expected to support, but even the lower ends of the intervening valleys were occupied, not by great native glaciers, but by lakes.

The conditions thus described may have some relation to the fact that while the porphyrites of the Cheviots have furnished the most abundant types of erratics in the drift of the Yorkshire coast, the granite, if present—which is not quite certain—is very rare.

10. *Report on the Erratic Blocks of the British Isles.*
See Reports, p. 283.

11. *Interim Report on the best Methods for the Registration of all Type Specimens of Fossils in the British Isles.*

12. *Report upon the Present State of our Knowledge of the Structure of Crystals.* See Reports, p. 297.

TUESDAY, SEPTEMBER 17.

The following Papers were read:—

1. *The Scottish Ores of Copper in their Geological Relations.*
By J. G. GOODCHILD, *F.G.S.*

The ores of copper occurring in Scotland appear, so far as their origin is concerned, to be referable to two primary categories. The first of these includes those minerals whose origin is evidently connected with the uprise of thermal waters; and the second includes those which are due almost entirely to deposition of materials carried down in solution from some rocks at a higher level to others below. The two methods of origin may be likened to the ebb and the flow of the tides.

To the first category belongs most of the Chalcopyrites occurring in Scotland, and with that mineral is to be included also Chalcocite and Bornite. These mostly occur in connection with mineral veins. A small percentage of other compounds of Copper with Sulphur appears to have originated in connection with certain eruptive rock of sub-basic composition. When these latter have been affected by dynamic metamorphism the process seems to have favoured the local concentration of the mineral which was formerly diffused. Hence several Epidiorites contain Chalcopyrites, apparently as an original constituent (if we regard their schistosity as original to that type of rock).

To the second category, that of the ebb-products or minerals of secondary origin, belong all the remainder.

Taking these in the order, and with the numbers, adopted by Dana, we have, first, (15) Native Copper. There cannot be much doubt that all the Scottish specimens of this are of secondary origin. The earlier stage seems to have been that of solution, along with those of the constituents of a sub-basic eruptive rock, through which, probably, the copper ore was originally diffused in very minute quantities. The decomposition of the rock by surface agencies has again converted

this into solution—probably in the form of carbonate—from which solution any one of various reagents, in most cases probably decomposing organic matter, has reduced the dissolved substance to the metallic state. In this form it has been deposited as thin sheets along the divisional planes of the rocks situated at a lower level than its point of origin. In the form of films of this kind it occurs at Boyleston, in Renfrewshire, where it is found in lavas of Lower Carboniferous age; and at Ballochmyle, in the joints traversing the marls of the New Red Rocks there. I may remark, in passing, that these rocks so closely resemble the Bunter Sandstone that I should never have hesitated to refer them to that horizon had not a different opinion regarding their age been expressed by the distinguished author of 'The Scenery of Scotland.'

Native Copper also occurs in the form of minute particles—possibly crystals—in some of the Prehnites of Boyleston and Glen Farg. Doubtless these varieties of Prehnite owe their colouring matter to the presence of this mineral, just as the ordinary green variety of Prehnite owes its colour to diffused compounds of copper of other kinds—possibly to Chrysocolla. The same metal also occurs at Boylestone, disseminated throughout some of the beautiful crystals of Calcite which line some of the drusy cavities of the lavas there. When Native Copper is enclosed in these crystals the external form is much more complex than where the metal is absent.

Some Chalcopyrites must undoubtedly be classed amongst ebb-products also, seeing that a second generation of crystals often occurs upon minerals whose secondary origin cannot be doubted. Atacamite has been claimed as a Scottish mineral, but, it seems to me, on insufficient grounds.

(224) Cuprite, as might be expected, occurs in connection with the other decomposition products of copper ores. Usually it occurs as one of the constituents in the compound known as Tile Ore; but occasionally, as at Glen Farg, it shows traces of crystalline exterior; or as at Boyleston, where Mr. Craig-Christie has got it in the capillary or velvet-like form. Some of the silicate of copper from Lauchentyre appears to me to be coloured red by Cuprite, which may also occur there in the free state.

(230) Tenorite has not yet been proved to occur as a separate Scottish mineral; but the black Chrysocolla from Lauchentyre and other mines in the neighbourhood may possibly owe its coloration to this mineral.

(288) Malachite calls for no special remark here beyond the statement that it does not appear to show crystalline termination at any locality in Scotland except at Sandlodge, in Shetland, where it seems to have been taken for Brochantite.

(289) Azurite is singularly rare in Scotland, and has not yet been found with visible crystalline faces. (290) Aurichalcite, (741) Linarite, and (739) Caledonite, well known as secondary products of the decomposition of veins containing Copper, do not call for any special remark in this abstract.

2. *A Revised List of the Minerals known to occur in Scotland.* *By* J. G. Goodchild.

The following list embraces the whole of the minerals whose claim to rank as good species and whose occurrence in Scotland seem to the author to be beyond doubt. The list will probably have to be extended:—

Graphite	Dolomite	Okenite
Sulphur	Magnesite	Gyrolite
Gold	Siderite	Apophyllite
Copper	Aragonite	Heulandite
Stibnite	Strontianite	Brewsterite
Molybdenite	Cerussite	Harmotome
Argentite	Malachite	Stilbite
Galena	Azurite	Laumontite
Chalcocite	Aurichalcite	Chabazite
Blende	Zaratite	Gmelinite

Pentlandite
Greenockite
Millerite
Niccolite
Pyrrhotite
Covellite
(?) Bornite
Chalcopyrite
Pyrites
Gersdorffite
Marcasite
Kermesite
(?) Bournonite
Tetrahedrite
Salt
Sal-ammoniac
Fluor
Quartz
Quartzine
Tridymite
Opal
Valentinite
Cervantite
Water
Cuprite
Corundum
Hæmatite
Ilmenite
Spinel
Magnetite
Chromite
Rutile
Plattnerite
Brookite
Pyrolusite
Turgite
Goethite
Manganite
Limonite
Brucite
Pyroaurite
Psilomelane
Calcite
Caledonite
Linarite
Gypsum
Epsomite
Morenosite
Melanterite
Alum
Hydrocerussite
Orthoclase
Microcline
Anorthoclase
Albite
Oligoclase
Andesine
Labradorite
Anorthite
Enstatite
Hypersthene
Augite
Ægirine
Spodumene
Wollastonite
Pectolite
(?) Babingtonite
Hornblende
(?) Glaucophane
Riebeckite
Beryl
Iolite
Nepheline
Sodalite
Garnet
Forsterite
Olivine
Wernerite
Idocrase
Zircon
Thorite
Topaz
Andalusite
Sillimanite
Kyanite
Datolite
Zoisite
Epidote
Allanite
Prehnite
Hemimorphite
Tourmaline
Staurolite
Pickeringite
Halotrichite
Wulfenite
Hatchettolite
Ozocerite
Fichtelite
Retinite
Levyne
Analcime
Edingtonite
Natrolite
Scolecite
Mesolite
Thomsonite
Muscovite
Zinnwaldite
Biotite
Phlogopite
Lepidomelane
Haughtonite
Chloritoid
Ottrelite
Clinochlore
Pennine
Prochlorite
Delessite
Serpentine
Talc
Saponite
Celadonite
Glauconite
Kaolinite
(?) Halloysite
Chrysocolla
Pilolite
Sphene
Apatite
Pyromorphite
Vanadinite
Vivianite
Erythrite
Annabergite
Wavellite
(?) Glauberite
Barytes
Celestine
Anglesite
(?) Vauquelinite
Leadhillite
Lanarkite
Torbernite
Bathvillite
Middletonite
Petroleum
Asphaltum
Elaterite
Albertite, &c.

The following are remarkable by their absence:—Calamine, Witherite, Leucite, Axinite, Anhydrite; and Marcasite and Fluor by their rarity.

3. *The Occurrence of Barium Sulphate and Calcium Fluoride as Cementing Substances in the Elgin Trias.* By Wm. Mackie, *M.A., M.D.*

Barium sulphate as a cement of sandstone was first noted by Professor Clowes in 1885 as occurring in Triassic rocks near Nottingham. Other localities in sandstones of the same age have since been noted, all of them in the north or centre of England.

Barium sulphate in the Elgin Trias was first observed by the author in 1895.

It occurs mainly in nodules which range in size from a hazel to a walnut disseminated through an extensive mass of sandstone along the coast of Elginshire, near Covesea Lighthouse, where in consequence of its influence on the weathering of the sandstones some unique results in rock sculpturing have been produced. Analyses of some of these nodules show that they contain as much as 37 per cent. of barium sulphate. In the nodules, the barium sulphate is shown by the microscope to directly envelope the grains of sand, except toward the periphery where rims of secondary quartz and ferric hydroxide come between the sulphate and the original grains.

The presence of calcium fluoride in rocks of the same age at Cummingston a little further to the west than the barium sulphate area was also determined by the author in 1895. The fluoride occurs in small white, often square-shaped, patches, showing lustre-mottling disseminated through the mass of the sandstone. Sometimes it occurs in aggregates which on section show that they are made up of cubes placed in juxtaposition. There are also occasional bands cemented throughout by calcium fluoride, but even in these lustre-mottling shows that it occurs in masses of closely placed cubes. The presence of fluoride was determined by obtaining a copious precipitate of gelatinous silica on heating the powdered sandstone with strong sulphuric acid and passing the evolved gas into water. As much as 25·88 per cent. of calcium fluoride was obtained by analysing an average specimen of the sandstone in detail. The microscope shows the presence of a colourless isotropic substance directly enveloping the sand grains. Towards the periphery, as in the case of the barium sulphate nodules, secondary quartz rims and ferric hydroxide are occasionally seen to come between the fluoride and the original grains.

The author disputes the explanation of Professor Clowes as regards the *raison d'être* of the barium sulphate, the presence of which has been ascribed by him to the double decomposition of barium chloride—which he finds present in some of the local deep well waters—by the soluble sulphates of the infiltrating waters. On the contrary, the presence of both barium sulphate and calcium fluoride is ascribed to the concentration of the waters of an inland lake from which these substances if present—and both of them are present in sea water—would naturally be deposited in the order of their insolubility as concentration went on. The presence of beds of common salt in the English Trias presupposes the existence of such a salt-impregnated lake over the southern area, and the same conditions may be reasonably extended to the Elgin area during the same geological period.

4. *The Pebble-band of the Elgin Trias and its Wind-worn Pebbles.* *By* WM. MACKIE, *M.A., M.D.*

The Cutties Hillock pebble-band, which has figured so largely in the discussion of the succession of the Elgin sandstones, is not, as has generally been contended, a pure localism. Two new openings into the Triassic rocks of the area show that it is present at five widely separated points. Its characters are constant in all. There is evidence that it is basal in position in the Triassic formation, and taking it as a datum line one is enabled to fix the relation of the Triassic to the underlying U.O.R. rocks with some certainty. It shows that the former overlie the truncated edges of the latter beds in a thin cake, which is probably nowhere more than 100 feet in thickness on a surface slightly inclined upwards from the south-east to the north-west, while the U.O.R. rocks steadily dip at almost constant angles in the opposite direction. Other facts definitely ascertained are, that the two series of rocks wherever they occur in proximity invariably show marked discordance of dip and strike, and that the Cutties Hillock area is detached from the other local areas of Triassic rocks, U.O.R. rocks having been traced all round it, and quite a mile intervening between it and the Spynie and Findrassie area to the north-west, in which interval U.O.R. rocks with discordant dip and strike also appear.

Another interest attaches to the pebble-band in that its pebbles, which are all

but exclusively of quartz, quartzite, vein quartz, and chert, show unmistakable evidence of sand-blast action.

'Pyramidal pebbles' are common, with surfaces showing different degrees of polishing. Some of them even present strongly concave surfaces and finer depressions beautifully polished. A considerable number show 'flaking' of their edges, and the surfaces so formed have subsequently been subjected to different degrees of polishing. The cherts are beautifully fretted, and exhibit in perfection the results of differential etching.

Inquiries as to definite orientation of the more polished surfaces of the pebbles have hitherto failed to yield results. The author believes that no such definite orientation obtains, and is of opinion that the pebbles had been subjected to continued sand-blast action in some other locality, and were suddenly and forcibly transferred by the action of water to their present position, where many of them were again subjected to further sand-blast action.

The result of the examination of the pebbles supports the author's contention, based on the microscopical characters of their constituent sand-grains, that the Cutties Hillock sandstones are really Triassic sand-dunes. Other reasons for arriving at the same conclusion are: the peculiar undulating bedding of the sandstones, differences in the mode of occurrence as well as ontological differences of the fossils from what obtain in the adjoining areas.

In the case of the other local Triassic areas deposition in water is assumed, though the débris had evidently in some cases for a long time previously been subjected to wind action on a land surface.

5. *The Occurrence of Covellite in Association with Malachite in the Sandstone of Kingsteps, Nairn.* By W. Mackie, *M.A., M.D.*

In a vein or fissure of about 1½ inch width in Kingsteps Quarry, Nairn, the sandstone is found to be impregnated with copper ore. The vein shows an indigo coloured centre of about ⅓ inch in width bordered by green margins of about the same dimension. Analyses of the different parts gave results which show that the copper ore exists in the centre of the vein, chiefly in the form of the monosulphide (CuS) and mostly in the form of malachite at the margins. The former, which is the mineral covellite, is apparently new to Scotland, as no mention is made of it in Heddle's 'Mineralogy of Scotland.' Nairnshire must also be recorded as a new locality for malachite.

6. *The Source of the Alluvial Gold of the Kildonan Field, Sutherland.* By J. Malcolm Maclaren, *B.Sc.*

In this field gold is practically confined to the small area drained by the Kildonan, Suisgill, and Kinbrace streams, all tributaries of the Ullie or Helmsdale. The rocks of this area are granites and quartz-, flaser mica-, and granulitic biotite-schists. The lines of demarcation between the various schists are at all times difficult to trace, since the whole countryside is covered with a thick deposit of the Glacial Drift. Fine flakes of gold have been found in many places in the Glacial Drift, supporting the inference that alluvial gold is more or less dispersed throughout. It is only in alluvium resulting from the action of the present watercourses that concentration of the Drift has been carried to such an extent as to attract commercial attention. The gold itself is found in nuggets and scales, the largest of the former weighing 2 oz. 17 grains. The scales present little evidence of rounding due to attrition or rolling friction. Veins of 'clean' quartz have been found in the upper waters of the Kildonan. One of these veins on analysis yielded gold. The writer concludes that the alluvial gold has been derived from the white quartz veins of the local schists (which are almost certainly metamorphosed sediments, possibly originally containing alluvial gold). The schists were crossed by glaciers travelling in a general south-easterly

direction, rudely disposing the comminuted auriferous quartz in 'leads' in the Drift. The present streams, cutting across the Drift, have more or less concentrated the gold. Profitable working of the deposit is precluded by the 'burden' of large stones, by the importance of the vested interests concerned, and by the inclemency of the winter season.

7. *Field Notes on the Influence of Organic Matter on the Deposition of Gold in Veins.* By J. Malcolm Maclaren, *B.Sc.*

The reducing action of organic matter on the soluble salts of gold was fairly established by the researches of Henry, Percy, Daintree, Sterry Hunt, and Newbery, and organic matter was considered for many years to be responsible for the great majority of the auriferous vein deposits of the world. With the publication of Skey's researches, and his demonstration of the fact that sulphides alone are competent to produce complete precipitation of gold from solution, the former theory was almost completely abandoned. The following cases, however, which have come under the writer's personal observation, admit at least of the possibility of precipitation by carbonaceous matter.

The reefs of the Gympie Goldfield, Queensland, underlie almost at right angles across the dip of the bedded greywackes, shales, sandstones, and limestones in which they are situated; but it is only where highly carbonaceous shales (the 'First,' 'Second,' 'Third,' and 'Phœnix' 'slates' of the miner) are intersected by quartz reefs that the latter are auriferous. The carbonaceous shales are certainly pyritous; but so also are the overlying and underlying beds in which the veins are barren.

The Croydon Goldfield, North Queensland, is in an area of metamorphic granite, containing much graphite. The reefs are more or less enclosed within walls of kaolinic matter highly charged with graphite. Where graphite is most abundant have been the richest auriferous deposits. On the other hand, broadly speaking, the presence of pyrites in a Croydon reef indicates poverty of content, and is considered as an unfavourable indication by miners.

The 'indicators' of the Ballarat Goldfield, Victoria, are thin beds of dark-coloured shales and slates, formed of a carbonaceous mud and containing a considerable percentage of iron pyrites. The main 'indicator' has been followed with few breaks for a distance of eight miles. The most profitable quartz reefs cross the 'indicators' almost at right angles, and the great bulk of the gold is found where the quartz reef has crossed and slightly faulted the 'indicator,' little gold being found at a greater distance than a yard from the intersection.

8. *The Source of Warp in the Humber.* By W. H. Wheeler, *M.Inst.C.E.*

It has frequently been stated that the mud or warp in suspension in the Humber is derived from the erosion of the cliffs on the Yorkshire coast, and the object of the paper is to show that it is physically impossible for the detritus eroded from those cliffs to be carried into the Humber, and that the material in suspension in the water is derived from detritus washed off the land drained by the Humber and its tributaries or eroded from their banks.

The drainage basin of the Humber covers 10,500 square miles, and embraces strata of various kinds of rocks, including estuarine deposits, glacial drifts, chalk, sandstone, and oolites.

The water in the zone extending around the junction of the Trent and the Ouse with the Humber, extending over a length of thirty-five miles, is very highly charged with solid matter in suspension, the maximum quantity being attained in the summer, when the downward flow of the fresh water is at a minimum, the quantity then in suspension amounting to as much as 2,240 grains, or nearly the third in a cubic foot of water. Above and below this zone the

quantity diminishes to 262 grains up the river Trent and 202 grains near the Albert Dock at Hull, while off Spurn, at the entrance to the river, there is no mud in suspension, but only a few grains of clean sand. The floor of the North Sea at the entrance is covered with clean sand and shells, the beach up to Grimsby also being covered with sand.

The solid matter in suspension is derived from the detritus washed off the land and poured into the river when freshets occur, or from the erosion of the banks of the river and its tributaries. The greater quantity that prevails in the more turbid zone is due to the material being kept in a state of oscillation by the ebb and flow of the tides when the quantity of fresh water flowing down is not sufficient to carry it out to sea.

The average quantity of solid matter contained in thirteen other English rivers when in flood is 200 grains in a cubic foot. The average rainfall within the watershed of the Humber is 29·60 inches, of which 10 inches may be taken as the quantity due to such rains as produce freshets. With these figures the normal total quantity of solid matter placed in suspension in floods may be put at three million tons in a year. A portion of this is carried out to sea in heavy freshets and the rest remains in the river in a state of oscillation.

The tendency in all rivers, whether fresh or tidal, is for material to work downward under the laws of gravity. The same quantity of tidal water that flows into the river has to flow out again, but its capacity for transporting material downwards is reinforced by the discharge of the fresh water.

The flood current in the Humber runs at the rate of four miles an hour, and its duration varies from six hours at Spurn to two and a half at Goole. It may be taken, therefore, that a particle of solid matter entering the Humber at Spurn Point would not be carried by the flood tide more than 20 miles up the river, or 25 miles below the point where the greatest amount of solid matter is held in suspension. On the turn of the tide it would be carried back again.

Allowing for the greater time the ebb current is running above the junction of the rivers, as compared with the flood, the material carried down on the ebb is 73 per cent. greater than that carried up on the flood.

Taking the length of the Holderness Cliffs as 34 miles, the average height at 12 yards, and the mean annual loss at $2\frac{1}{4}$ yards, the mean quantity falling on the beach is about $1\frac{3}{4}$ million cubic yards a year, of which about 40 per cent. consists of stones, gravel, and coarse sand, leaving less than a million cubic yards to be washed away. The foot of the cliffs is only reached for about four hours at high water of springs, that is, by 260 tides in a year, the average quantity of alluvial matter for each tide being 3,728 cubic yards.

The drift of the tidal current towards the Humber lasts $3\frac{1}{2}$ hours, and runs at a velocity of $2\frac{1}{2}$ miles an hour; the greatest distance a particle of solid matter put in suspension at the point of mean distance, 20 miles from the Humber, could be carried southward is $8\frac{3}{4}$ miles; when this distance is reached the tide would turn and the particle would be carried northward for 16 miles, or 28 miles away from the Humber.

It is, however, quite improbable that a particle of matter placed in suspension at the foot of the cliffs could ever reach the main current going to the Humber. Owing to the Yorkshire coast being in an embayment the main tidal current does not approach nearer the coast than the 6-fathom line, or a mile away from the coast. The current of the flowing tide sets into the embayment towards the coast. Even if a particle from the cliffs could overcome this shoreward set and traverse the water contained in this mile of water in an opposite direction, so as to be brought into the main southerly-going current, the quantity of solid matter brought into suspension would only be sufficient to supply one grain to 14,000 cubic feet of water.

It is evident from the above facts that it is not possible for the detritus from the Yorkshire coast to reach, much more to be carried up, the Humber.

9. *On the Alterations of the Lias Shale by the Whin Dyke of Great Ayton, in Yorkshire.* By GEORGE BARROW.

[Communicated by permission of the Director of the Geological Survey.]

The examination of the least altered portion of the rocks of the Highland series in the area between Blairgowrie (Bridge of Cally) and Stonehaven has shown that the grits are composed of practically unaltered grains or small pebbles of quartz and oligoclase felspar set in a matrix of an unusual character, and difficult to understand, as all traces of clastic micas have been obliterated from it. It occurred to the author that this was due to heat action, and to test this point slices of baked Lias shale were prepared, the specimens being taken from the edge of the well-known Cleveland Dyke at Great Ayton. At six inches from the edge of the dyke the clastic micas are large and abundant, but at the contact they are entirely digested, and material like the matrix of the Highland grit is produced. The minute pebbles are not affected in any way, and retain their original form, size, and optical properties. It is thus shown that in entering the Highland area we begin with rocks which, though little altered, owe that alteration entirely to heat action.

10. *On Cairngorms.* By E. H. CUNNINGHAM CRAIG, *B.A.*

The search for these crystals was formerly a very profitable industry in the districts contiguous to the great granite masses, but it has now been practically abandoned. The cairngorms were obtained by digging shallow pits and trenches in the decomposed granite and débris which covers most of the flat hill-tops, and also appears in many of the corries. The presence of vein-quartz, muscovite, large crystals of orthoclase and graphic intergrowths of quartz and felspar in the loose débris have been recognised as indications of the existence of the cairngorm-bearing veins. Examination of the cliff sections in the deep corries reveals the presence of vertical or highly inclined veins of fine granite intruded in the coarser surrounding rock. These veins are more acid than the normal granite, and contain drusy central zones in which the crystallisation is coarse. These central zones are characterised by the presence of graphic intergrowths, muscovite plates, and, where the druses are sufficiently large, idiomorphic crystals of orthoclase and more or less smoky quartz. Beryl is also present in some cases.

These idiomorphic quartzes are the cairngorms, but are only valuable when large and well coloured.

The veins probably represent the intrusion of more highly differentiated material from the underlying magma into fissures due to contraction on cooling, while the druses have probably a similar origin, and have been filled with highly acid solutions from which the crystallisation took place.

11. *On the Circulation of Salt and its Geological Bearings.*[1] By WILLIAM ACKROYD, *F.I.C., Public Analyst for Halifax.*

During storms salt is driven from the sea far on to the land, is dissolved by rains and carried back to the sea; in calm times the phenomenon is also in progress. Various computations have been made of the amount of salt deposited on the land in this manner from 24·59 lb. per acre per year at Rothamsted to 641 lb. at Pennicuick. The writer estimates that during 1900–1901 there was 172·3 lb. per acre per year deposited on the Pennine Hills, nearly midway between the Irish Sea and the German Ocean, at an altitude of over 1,000 feet above sea-level.[2]

It is shown that for the Millstone Grit and the limestone districts of Yorkshire,

[1] Published in full in the *Geological Magazine*, December 4, vol. viii. p. 445, October 1901.

[2] Ackroyd, 'Researches on Moorland Waters,' Pt. II., *Journ. Chem. Soc.*, vol. xxix. p. 674.

as well as for a belt of American coast some 200 miles broad, this cyclic sea-salt forms fully 99 per cent. of what is carried to the seas by the rivers. Professor Joly, in his estimate of the age of the earth, only allows 10 per cent.

A study of the phenomenon is also of importance in attempts to apportion the causes of the saltness of inland lakes and salt hills, which may be due to: (1) salt transported from a contemporary sea, or (2) salt derived from solvent denudation, or (3) to varying degrees of these two influences. Reasons are given for regarding the saltness of the Dead Sea as being largely due to the first cause, and of the Caspian to the second.

12. *Notes on the Occurrence of Phosphatic Nodules and Phosphate-bearing Rock in the Upper Carboniferous Limestone (Yoredale) Series of the West Riding of Yorkshire and Westmorland Border. By* JOHN RHODES, *of the Geological Survey.*

By kind permission of the British Association Committee on Carboniferous Zones I am enabled to announce the discovery of phosphatic nodules and of a rock having a phosphatic matrix in the Yoredale rocks of the following localities:—

Phosphatic Nodules. Far Cote Gill, East Slope of Swarth Fell, Westmorland.

These nodules occur along with ironstone septaria in blue shales which rest on the top silicious beds of the Underset Limestone.

The nodules are confined to the lower 5 feet of the shales, and are more numerous in the lower half than in the upper half.

In same gill, and resting on the chert of the Little Limestone, there is a layer, 3 inches in thickness, containing phosphatic nodules embedded in a fine clayey matrix. It is sprinkled throughout with glauconite grains and angular chips of quartz, and is overlaid by ironstone shales.

At the same horizon as above, but $2\frac{1}{4}$ miles to the S.E., there occurs in a gill that runs from Lambfold Crags to Lunds Church, 2 miles W. of N. of Hawes Junction, a layer of rock, 3 inches in thickness, with a phosphatic matrix throughout. This layer, which has a crust of brown iron ore, is rich in glauconite and quartz grains, and also contains fragments of conodonts, &c.

Phosphatic Nodules. Goodham Gill, East Slope of Swarth Fell, 2 miles N.W. of Hawes Junction, Yorkshire.

The phosphatic nodules at this locality occur throughout a limestone which varies in thickness from 3 to 6 inches. This layer is underlaid and overlaid by shale in more or less rotten condition.

The horizon is doubtful, but it appears to be about 170 feet over the Little Limestone.

From the upper surface of the top bed of the Crow Limestone, Cartmere Gill, East Baugh Fell, Grisdale, $2\frac{1}{2}$ miles W.N.W. of Hawes Junction, I have obtained a solitary example of a phosphatic nodule.

The phosphatic nodules and phosphatic matrix examined show sponge spicules, but these are for the most part fragmentary: some are of crypto-crystalline silica, some replaced by calcite, whilst the axial canals are often filled with the same phosphatic material as the matrix.

The spicules are referred to hexactinellid and to monactinellid sponges.

I am very much indebted to Dr. G. J. Hinde for notes on the sponge remains, and also to Dr. W. Pollard for testing the phosphates.

13. *Note on the Discovery of a Silicified Plant Seam beneath the Millstone Grit of Swarth Fell, West Riding of Yorkshire. By* JOHN RHODES, *of the Geological Survey.*

By kind permission of the British Association Committee on Carboniferous Zones I am enabled to record the discovery of a silicified plant seam beneath the Millstone Grit at Swarth Fell, and two miles N.W. of Hawes Junction.

The exact geological position of the overlying strata is doubtful, but apparently they occupy the horizon of the grindstone or ganister of the district.

At this particular place, however, the grindstone or ganister is absent, and its place is taken by flaggy silicious limestones with marine shells and by a bed of highly silicious grit with plant remains, the latter resting more or less directly on the silicified plant seam.

Chert occurs, probably as lenticles in the uneven surface of the seam, and contains a mass of detached silicious sponge spicules, apparently rod-like bodies, which may belong to the anchoring ropes of hexactinellid sponges. In the same chert are included fragments of silicified plant remains beautifully preserved.

In the plant seam included pebbles of silicious grit occur, which contain a few spicules similar to those in the chert, and also plant remains. The plant seam rests on a layer of silicified shale containing a few fragmentary sponge spicules, mostly rod-like forms, one piece belonging to an hexactinellid sponge. The beds below are more or less rotted clay shales with ironstones nodules.

I am indebted to Dr. G. J. Hinde for notes on the sponge remains directly associated with the plant seam. The plants have not been determined, but have been placed in the hands of R. Kidston, Esq., Stirling.

WEDNESDAY, SEPTEMBER 18.

The following Papers and Reports were read:—

1. *On the Bone-beds of Pikermi, Attica, and on Similar Deposits in Northern Eubœa. By* A. SMITH WOODWARD, *LL.D., F.R.S.*

At the suggestion of the British Minister at Athens, Sir Edwin H. Egerton, K.C.B., the Trustees of the British Museum recently undertook a series of excavations in the well-known bone-beds of Pikermi in Attica, and I was honoured by being entrusted with the supervision of the work. The owner of the estate, Mr. Alexander Skousés, former Minister of War, most cordially assented, and gave every possible facility for the undertaking; while Sir Edwin Egerton's unflagging interest and zeal combined to ensure the greatest success. My wife and I went into residence at the farm early in April, and we continued to occupy the simple but comfortable room which Mr. Skousés had kindly placed at our disposal until the cessation of digging in the middle of July.

During much of the time we were accompanied by Dr. Theodore Skouphos, Conservator of the Geological Museum of the University of Athens, which claims some share of the results of all such excavations made in Greece. We have to thank him for much help in dealing with the workmen, who spoke only a language with which I was at first unfamiliar.

The bones are occasionally exposed by the small stream in the ravine of Pikermi, and they seem to have been first observed by the English archæologist, George Finlay, who presented some to the Athens Museum in 1835. Three years later a Bavarian soldier took a few specimens to Munich, where Pikermi and its fossils were first brought to the notice of the scientific world by Professor Andreas Wagner. Within the next decade more bones were sent to Munich by Lindermayer and described by Wagner; while during the winter of 1852–53 the young Bavarian naturalist Roth made the great collection which was described by himself and Wagner in 1854, and still constitutes one of the chief treasures of the Munich Old Academy. About the same time Choeretis presented a few specimens

to the Paris Museum; while the late Professor Mitzopoulos—uncle of the present distinguished Rector of the University of Athens—made a valuable and extensive collection for the Athens Museum, which seems to have remained unnoticed until 1883, when the late Professor Dames, of Berlin, studied it and wrote a brief account of some unique specimens contained in it. By far the most important excavations hitherto made at Pikermi, however, are those which were undertaken by Professor Albert Gaudry, under the auspices of the Paris Academy of Sciences, between 1855 and 1860. These researches made known nearly all the essential facts concerning the extinct mammalian fauna entombed in the Pikermi formation, and led to several brilliant generalisations first published in Professor Gaudry's well-known work on the geology and fossils of Attica in 1862. During the last forty years only insignificant diggings have been attempted, among them being those of the late Professors Neumayr, of Vienna, and Dames, of Berlin.

Owing to the permanent mark left by former excavations it was easy to choose sites for the new explorations of the British Museum. Three pits dug in continuation of former workings soon yielded bones, and eventually furnished a very extensive collection. Two trial pits at other points and in slightly different horizons produced nothing except two decayed bone-fragments. Water still occurs even in dry weather a little beneath the bed of the stream; but the difficulties from this source are now much less than formerly owing to Mr. Skousés' system of irrigation, by which the flowing stream of the ravine is usually diverted at a point high up in its course.

The Pikermi formation has already been well described by Professor Gaudry. It consists chiefly of red marl, varied with lenticular masses of rounded pebbles and occasional yellowish sandy layers. Some of the pebble-beds are cemented into hard conglomerate. The materials are such as might have been derived from the mountain mass of Pentelicon, which forms the neighbouring high ground, the marl itself being apparently the detritus of marble or other calcareous rock. The formation is of great extent in Attica, and has only attracted special notice at Pikermi because a stream happens to have cut a deep ravine through it and exposed fine sections of the beds.

As already observed by Professor Gaudry, the bones at Pikermi occur in two definite horizons, those in the lower bed being less fragile and better preserved than those in the upper bed. In two of our new pits, where the upper horizon is well exposed, it is subdivided into two distinct layers by a nearly barren deposit of marl from 30 to 45 cm. in thickness. The rotten nature of the bones is partly due to their having been close to or at the surface and eroded by the present stream before being covered by the three or four metres of superficial gravel which now preserves them. The bones are also broken by the penetrating rootlets of trees. The lower horizon is at a depth varying from one to two metres below the upper horizon, and thus secure from destruction by surface agencies. Like each of the two upper bone beds, it is rarely more than 30 cm. in thickness; while the marl above and below it is almost destitute of bones, rarely yielding more than rotten fragments, but quite prolific in scattered land and fresh-water shells. The deepest excavations beneath the lower bone-bed descended for about three and a half metres and furnished the bone-fragments and shells throughout.

So far as can be judged at present from the new excavations, the three bone-beds of Pikermi are all of the same nature and contain the same mammalian remains. The bones are massed together in inextricable confusion, and are often mixed with a few pebbles. Large and small bones, whole specimens and splintered fragments, all occur together; but the small bones are usually most numerous at the bottom of the layer. Several specimens of approximately the same shape and size are often met with in groups, as if they had been sorted by water in motion. On one occasion, for example, the scattered remains of many gazelles were found together; in another spot there were several skulls of *Tragoceras* in one mass; in other cases nearly all the bones belonged to limbs of *Hipparion*; while one area was specially characterised by pieces of vertebral column of ruminants and *Hipparion*. The elongated bones and elongated groups, however, were never observed to trend in one definite direction, but were always

disposed quite irregularly, thus indicating that in the region where the bones eventually accumulated the water by which they had been transported either became still or moved only in gentle eddies.

Very few nearly complete skeletons occur, and even when chains of vertebræ are preserved most of the ribs are lacking. The only approximately complete skeletons observed during the recent excavations were those of some Carnivora (*Ictitherium*, *Metarctos*, and *Machærodus*). It is, however, obvious that many of the bones were still held together by ligaments at the time when they were buried, for numerous complete feet and nearly complete limbs are found with all the bones in their natural position. It is also to be noted that in most cases these limbs are sharply bent, so that the two or three segments are almost parallel, as if they had retained the contraction assumed at death. Some decomposition of the soft parts had already taken place even in these instances; for a few of the phalanges of the hipparions and ruminants are often wanting when the other bones of the limb are still in their natural association, while the phalanges of the rhinoceros-feet seem to be always lost, though the three associated metapodials are quite common. Similarly, the loosely articulated mandible of the Ungulata is nearly always removed from the skull; it is only commonly preserved in place in the Carnivora and Quadrumana.

The majority of the bones are quite isolated, and most of the skulls of the antelopes are so much broken that only the frontlets with horn-cores remain. A large proportion of the limb-bones are also sharply fractured, some having completely lost both extremities; and small pointed splinters of bone—apparently most of *Rhinoceros*—are often very numerous. Some of the breaking must have taken place before the soft parts had entirely decayed, as is shown by certain feet of *Rhinoceros* and many limbs of *Hipparion* and antelopes. In a few cases I found the three associated metapodials of *Rhinoceros* with the distal ends as sharply removed as if they had been cut off with one blow of a hatchet. In several instances I carefully extracted the nearly complete hind limbs of *Hipparion* from the soft marl, and in all except one I found that the tibia ended abruptly in a sharp, oblique fracture at its middle, with no trace of the proximal end of this bone or of the femur. Moreover, nearly all the isolated tibias of *Hipparion* were similarly fractured; while among about fifty examples of humerus of the same animal only three complete specimens were found, all the others being sharply broken at the weakest point of the shaft. It is therefore evident that the limbs were often torn from the trunk by a sharp break at their weakest point before the decomposition of the soft parts had proceeded far enough to destroy the ligaments.

The new researches make scarcely any additions to the known fauna of the Pikermi bone-beds, and confirm Professor Gaudry's statement that the smaller rodents, insectivores, and bats are absent. The only striking discovery consists in fragmentary evidence of a gigantic tortoise, at least as large as the largest hitherto found in Europe. Many specimens, however, afford important new information concerning the species already described. Notable among these are a few portions of skull and a mandible of *Pliohyrax*, a skull of *Samotherium*, a skull of *Hystrix primigenia*, and the greater part of a skeleton of *Metarctos*. Remains of *Hipparion* are the most abundant fossils, and the new series of specimens illustrates variations and growth-stages more satisfactorily than any collection hitherto made. Isolated bones and skulls of *Rhinoceros* are also common; and antelope-remains occur everywhere in great profusion. Limb-bones of Giraffidæ are found abundantly in the lower bone-bed. *Mastodon* is rarer; but two small skulls were obtained from the new excavations, and several very large limb-bones were found. Among Carnivora *Ictitherium* is the commonest form; but remains of *Hyæna* are not infrequent, and evidence of four individuals of *Machærodus* was discovered during the present diggings. Coprolites of some bone-feeding Carnivore, probably *Hyæna*, also occur. Skulls and other portions of *Mesopithecus* are frequently met with. The shells of the small *Testudo marmorum* are sometimes complete, but always lack the skull and other bones of the skeleton. The Chelonian shells themselves are, indeed, more frequently broken and disintegrated;

and a large proportion of the bone fragments discovered between and below the bone-beds are recognisable as pieces of them. It is noteworthy that a good specimen of *Testudo marmorum* was found in the marl between the upper and lower bone-beds in one pit; and a small undetermined snake was discovered in a similar position in another pit.

While the excavation of these fossils was in progress at Pikermi, Mr. Frank Noel, of Achmet Aga in Northern Eubœa, accompanied Sir Edwin Egerton on one of his visits. He recognised that the Pikermi marls were similar to some containing fossil bones on his own estate. He also perceived the identity of the remains of *Hipparion* at Pikermi with the commonest fossil bones with which he was familiar at Achmet Aga. Many years ago he had sent some of these bones to the Athens Museum, but they seem to have been lost and had never received any attention from the Greek naturalists. He therefore invited the British Museum to examine the discovery on his estate and decide whether or not the extinct Pikermi fauna was there represented.

A brief visit to the locality where the bones occur, near Achmet Aga, sufficed to confirm Mr. Noel's anticipations. The interesting spot is in a deep ravine on the steep slope just below the village of Drazi at an elevation of nearly 200 metres above the sea level. The torrent has cut through a thick deposit of red indurated marl much like that of Pikermi, and bones are noticeable in the section at many points. Three days' digging at one place revealed two bone-beds separated by a thin layer of marl. The bones seem to be as abundant and varied as those at Pikermi, and they exhibit exactly the same features. *Hipparion* is again the commonest fossil, and mingled with the complete bones are splintered fragments Land and fresh-water shells also occur in great abundance, especially a species ot *Planorbis*.

Nearly all the bones discovered during this brief visit were too rotten for preservation; but the weathered face of the section alone was explored, and the fossils would doubtless be found in good condition further inwards. Among them could be recognised, besides the innumerable remains of *Hipparion*, parts of a skull and tibia of *Rhinoceros*, a frontlet of *Gazella brevicornis*, jaws of a small ruminant, a large ruminant metapodial (probably *Samotherium*), part of a skull and mandible of *Ictitherium*, and some small carnivore vertebræ. There was also part of the skull of a small species of *Orycteropus*, which I was able to preserve and bring for comparison with the skull of the same genus from Samos now in the British Museum.

From these observations it is evident that the Pikermi bone-beds are not merely a local accident, but are due to some widespread phenomena. The two localities described are about sixty miles apart, and seem to be situated in two distinct Tertiary basins separated by a barrier of Cretaceous limestones and earlier rocks. Whatever the catastrophe may have been by which the animals were suddenly destroyed, it clearly happened in both places at least twice if not three times within a comparatively short period. The powerful force which broke up and transported the bodies before they had completely decomposed was probably the same in each case; while the final resting place of the bones both at Pikermi and Drazi must have been beneath comparatively tranquil water where they could be quickly buried in mud. The absence of all trace of vegetable matter is curious; but the most plausible explanation of the broken limbs and torn portions of trunks seems to be that the bodies were hurried by torrential floods through thickets or tree-obstructed watercourses before they reached the lakes in which they finally rested. Accompanying stones in rapid motion may account for some of the bone-fragments.

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2. *The Fayum Depression: A Preliminary Notice of the Geology of a District in Egypt containing a New Palæogene Vertebrate Fauna. By* Hugh J. L. Beadnell, *F.G.S., F.R.G.S., of the Geological Survey of Egypt.*

The Fayum is a large circular depression in the Libyan Desert, some fifty miles south-west of Cairo. The lower part—an area of some 1,500 square

kilometres—is occupied by a large lake, the Birket el Qurun, and an inhabited cultivated district, irrigated by a canal, entering the depression from the Nile Valley. This central part is surrounded by an arid desert, rising by a series of escarpments to varying heights, those on the north side attaining an elevation of 400 metres above the lowest part of the depression. The depression is cut out in rocks of Eocene and Oligocene age, but within the hollow, still younger deposits, of Pliocene and Post-Pliocene date, are found.

The lowest beds exposed in the depression are the clays, marls, and limestones with *Nummulites gizehensis* of Middle Eocene age. These are succeeded by a group of marly limestones and gypseous clays which largely underlie the cultivated alluvium of the Fayum. The latter are followed by a series consisting of clays, sandstones, and calcareous grits, some beds of which are characterised by the abundance of *Operculina* and small nummulites. This last group is followed by the uppermost Eocene marine beds, an alternating series of clays, sandstones, and limestones, the '*Carolia* beds' (equivalent to the upper Mokattam of Cairo), characterised by an abundant invertebrate and vertebrate fauna.

Above the *Carolia* beds, and well marked off from them both lithologically and palæontologically, is found a great thickness of variegated fluvio-marine sands, sandstones, clays, and marls, divided near the summit by one or more intercalated lava sheets.

The beds above the basalt are certainly of Oligocene age, and probably a large part of those below; but the basal beds appear to represent the Upper Eocene, there being evidently a perfectly gradual transition from Eocene to Oligocene in this area.

During a survey of the area in 1898 the author found that certain strata of the series were veritable 'bone beds,' being crowded in places with the remains of crocodiles, ribs of cetaceans, fish bones, and coprolites.

In May 1901 he returned to the district with the special object of re-examining and more carefully searching the most promising beds, and on this expedition he was accompanied by Dr. C. W. Andrews, of the British Museum (Natural History). On their return journey to Cairo they were most fortunate in crossing the Eocene escarpments at a point where a considerable number of marine and terrestrial vertebrate remains lay exposed on the surface of the bone beds, and a fortnight's careful work resulted in an unique collection of entirely new mammals and reptiles.

A preliminary description of the most interesting of these is now being published by Dr. Andrews in the 'Geological Magazine,' and Capt. Lyons intends to issue as soon as possible a complete survey memoir on the district by the author, with a description of the vertebrate remains by Dr. Andrews.

3. *Report on the Movements of Underground Waters of N.W. Yorkshire.* See Reports, p. 337.

4. *On the Physical History of the Norwegian Fjords.* *By* Professor EDWARD HULL, *M.A., LL.D., F.R.S., F.G.S.*

That the Norwegian fjords were originally river-valleys is a statement which scarcely admits of controversy. In their form, outline, and topographical position they are simply prolongations of the valleys which descend into the sea partly submerged; and if the land were still further submerged, as it once was to the extent of 200 metres according to Andr. M. Hansen, the fjords would be prolonged beyond their present inland limits without much variation of form.

The process of valley erosion by rain and river action is nowhere in Europe more admirably exemplified than in Western Norway, and the process may be supposed to have been in operation in the early formation of the fjord channels

themselves before the epoch of submergence. But when we come to examine the form of the channels, as shown by the soundings marked on the Admiralty charts, we find ourselves confronted by the remarkable fact that the beds of the channels descend to very great depths, far exceeding those of the outlets where the fjords open out upon the floor of the North Sea. Now as river valleys must necessarily increase in depth from their sources to their outlets, we are here brought face to face with a physical problem which apparently is inconsistent with our view of the original character of these channels as stated above. To the solution of this problem we must now shortly apply ourselves.

2. *General form of the fjord-beds.*—The numerous soundings laid down on the Admiralty charts of 1865 and 1886 enable us to determine with accuracy the form of the submerged portions of the fjords. Using these soundings, and by their aid laying down the isobathic contours, we arrive at results sufficiently remarkable. In the case of the Hardanger, the Feris, the Sogne, the Nord, the Vartdals, and the Stor Fjords with their branches we find that shortly after passing the entrance from the outer sea and the chain of islands which fringes the coast of the mainland they rapidly descend to great depths, which are continuous for long distances inland, and then gradually become shallower toward the upper limits, where they pass into river valleys characterised by terminal moraines of ancient glaciers, or old sea terraces. In carrying out the mapping of the contours the author has adopted the following soundings:—

(1)	Those of the	100-fathom	contour	(600 feet).
(2)	,, ,,	200	,,	,,	(1,200 feet).
(3)	,, ,,	400	,,	,,	(2,400 feet).
(4)	,, ,,	600	,,	,,	(3,600 feet).

The floor of the Sogne Fjord descends to even greater depths than the last of these, viz., 661 fathoms (3,966 feet), which is reached in the case of the Sogne Fjord at a distance of about 25 miles from the entrance. At the entrance the depth seldom exceeds 100 fathoms (600 feet), and is generally less; but once the deep water is reached there is little change of level for long distances. As regards the cross-section of the principal fjords a glance at the charts shows that they retain the form of narrow channels with little variation in breadth, receiving tributaries on either hand and bounded by steep or precipitous walls of rock, as in the case of the valleys, of which they are only prolongations under the surface of the sea.

3. When endeavouring to account for the peculiar form of the fjords and the depth of their floors over the central portions we must not forget that these old river valleys were the channels of great glaciers during the Post-Pliocene or Glacial period, and that glacial erosion has contributed to the deepening process. Some Norwegian geologists, such as Hansen,[1] attribute to this deepening of the original channels by glacier erosion on the one hand, and to the piling up of enormous masses of moraine matter at the entrance on the other, the great disparity of the depth of the fjords at the inner and outer stages of their course. To the latter cause the author fully assents; but he is doubtful whether glacier erosion has had the effect of adding many hundreds of feet to the depth of the original floor of the valleys. But leaving this question, we have to consider a second problem: by what means did the original rivers empty themselves into the ocean before the Glacial period, when there was neither deepening of the floor by glacial erosion nor shallowing by moraine matter? Previous to the Glacial epoch the rivers must, in the author's view, have entered the outer ocean through channels which cannot now be clearly traced by soundings over the shallow floor of the North Sea. At the same time it is certain that it was by such channels that they reached their ultimate destination in the Arctic Ocean, because rivers as they flow seawards must necessarily descend to lower levels. This being so, it follows that the channels do actually exist, though they may not be traceable by the soundings over the flow

[1] *Norway*, edited by Dr. Sten Konow and Karl Fischer, May 1900. Translated by J. C. Christie, Miss Muir, and others.

of the comparatively shallow North Sea, and we have to consider why it is that they are untraceable.

The cause appears to be closely connected with the subsequent submergence in later or Post-Glacial times, as indicated by the raised beaches and terraces.[1] During this epoch the glaciers had only partially disappeared or receded from the lower valleys. Great quantities of mud, sand, gravel, and boulders would be carried down by the streams and distributed by floating ice over the sea-bed. By such material the whole floor of the North Sea has been overspread to unknown depths, and owing to the agency of tides and currents would have been swept into the deep channels of the pre-existing rivers. The author is convinced that were it possible to strip the floor of the North Sea of its sedimentary covering these channels would be found traversing the floor of the continental platform, and ultimately opening out by cañon-like channels on the floor of the Arctic Ocean.

The phenomena here observed, or inferred, have their representatives along the coasts of the British Isles and Western Europe. In both cases there is the shallow continental platform, terminating in a deep and rapid descent to the floor of the abyssal ocean, and traversed by channels of ancient rivers traceable by the soundings in the case of Western Europe, or inferential in the case of Western Scandinavia. In a few cases these channels are for short distances clearly indicated on the charts, as, for example, in the case of the Bredsund Dybet, which is a prolongation of the Stor Fjord out to sea, between the islands of Godo and Harejdo in lat. 62° 30′, with a general depth of 100 fathoms below the adjoining floor of the sea; and there are a few other similar cases.

Outline of the physical history of the fjords.—As connected with the past history of the Norwegian fjords the following appear to be the most important stages:—

1st (Earliest) Period.—Continental conditions; Archæan rocks; river erosion begins.

2nd Period.—Partial submergence in early Silurian times.

3rd Period.—Elevation of land during Mesozoic and Tertiary periods; further deepening of river channels.

4th Period.—*Quaternary.* Early Glacial: great elevation of land and ultimate extension of snowfields and glaciers. Ice filling the valleys and moving out to sea.

5th Period.—*Quaternary.* Post-Glacial: subsidence and partial submergence of land: retreat of the glaciers. Icebergs and rafts covering the adjoining sea. Amelioration of climate.

6th Period.—*Recent.* Re-elevation to approximately present position with regard to the outer ocean. Formation of raised beaches (strand linien).

The paper concluded with a comparison between the above physical features as they occur in Norway with those of Scotland.

5. *On the Origin of the Gravel-flats of Surrey and Berkshire.*[2] *By* HORACE W. MONCKTON, *F.L.S., V.P.G.S.*

On the south of the Thames flat expanses of gravel are largely developed. They lie at various levels from 600 feet O.D. at Cæsar's Camp, Aldershot, down to almost sea-level in the Thames valley near London.

The gravel is of variable thickness; perhaps 15 feet is about the average.

There are similar gravel-flats north of the Thames, but there drift questions are complicated by the presence of glacial beds.

[1] According to Professor Reusch the terraces with marine shells reach an elevation of about 200 metres (620 feet) in the Trondheim district; but the author during a recent visit was unable to observe any higher than 250 feet south of this position.

[2] Published in full in the *Geological Magazine*, December 4, vol. viii. November 1901.

The author suggests—

1. That the gravels are river gravels formed since the country last rose above the sea;

2. That the process of elevation was not continuous, but that short periods of rapid movement were separated by long periods of repose;

3. That the gravel-flats are the work of the rivers during the periods of repose;

4. That the earth-movements did not affect the whole area uniformly, and that local depressions occurred.

In support of these conclusions the author refers to the step-terraces so common in the fjords and to the old coast-plain and shore-lines which occur above and below the present sea-level on the Norwegian coast.

As evidence of local depression, he refers to the deep channel of Drift in the valley of the Cam, described by Mr. W. Whitaker,[1] and to the great thickness of the *Corbicula fluminalis* bed at Crayford.

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6. *On the Occurrence of Diorite associated with Granite at Assouan, Upper Egypt.* *By* Alexander Somervail.

Immediately below the front of the Cataract Hotel there is exposed an interesting section of the reddish granite of the neighbourhood. It is notable for a mass of dark diorite, which seems to cut it as a vein or dyke, running in an E.N.E. and W.S.W. direction.

The breadth of this dyke-like mass is variable, but on an average it is about three feet wide.

The walls of both are as a rule sharply defined, without any apparent passage of the one into the other, although at some portions of the margin of the diorite there are a few red crystals of the felspar of the bounding granite.

There are, however, about the central portion of the diorite, crossing it at right angles, two small veins of the reddish granite of the parent mass. One of these is only about quarter of an inch wide, and the other about two inches in width.

These two veins are both in colour, and also in composition, exactly the same as the mother rock; and are not continued into the parent mass as distinct veins, but are essentially a part of the granite itself.

The author did not enter upon any theory of explanation, but it is, he thinks, obvious that the granite and diorite are not separated from each other by any great difference of age.

7. *Note on some Hornblende Porphyrites of Victoria (Australia).* *By* James Stirling, *Government Geologist of Victoria.*

The existence of auriferous quartz veins associated with a class of eruptive rocks, which are intrusive to the Upper Silurian formation (shales, sandstones, conglomerates, and limestones) of Victoria has long been known. The frequent occurrence of hornblende in this class of rock has led to the use of the term *diorite* for most of the dykes, although marked differences in mineral composition and structure were frequently observed. During a recent geological and underground survey of the Walhalla Goldfield, where the dykes were classed as *diorites*, I caused a number of samples of the dykes to be selected and sliced for petrographic investigation, with the result that many of the intrusive rocks were found to belong to several different classes, in which hornblende was either wholly absent or but sparingly represented, being replaced by mica-forming mica-felsites, &c. This inquiry led to a closer examination of the well-known Wood's

[1] *Quart. Journ. Geol. Soc.*, vol. xlvi. p. 333.

Point diorites, in which hornblende is notably present, with the result stated in the accompanying petrographic note. It is intended to continue the systematic investigation of all the Victorian so-called *diorites*, particularly those with which auriferous quartz veins are associated.

In this investigation I shall have the valuable co-operation of Mr. F. P. Mennell, an Australian student at the Royal School of Mines, London.

The following brief description is intended as a preliminary note:—

WOOD'S POINT, VICTORIA.

Slide 277.—This slice was cut from a dark coloured, even-grained rock of granitic aspect. The specific gravity is high (2·9). Black hornblende is the most conspicuous constituent; ilmenite and pyrites can also be recognised by their characteristic colour and lustre. Under the microscope the rock does not show that simplicity of structure which might be inferred from its appearance in hand specimens. Hornblende is still the mineral which gives a distinctive character to the rock; but the whitish material with which it is associated, though much decomposed, is at once seen to be of a complex nature.

Constituent Minerals: Hornblende.—This mineral occurs in large granules, often showing crystal faces, though the outline is frequently too indefinite for the form to be determined with precision. The prismatic cleavage is generally well marked, though some crystals show irregular cracks. The colour is in most cases brown, though some of the crystals are of a greenish tinge, and a few are quite colourless. The coloured varieties exhibit strong pleochroism (fairly deep brown to almost colourless). Sections showing only one set of cleavage traces give a maximum extinction angle of 20°.

Felspar.—The predominant felspar is evidently plagioclase, though owing to its decomposed state and the absence of twin lamellation or cleavage traces it is difficult to assign it with certainty to its proper position in the albite-anorthite series. It seems, however, to be a basic oligoclase, and it is notable that in one or two instances it presents crystal faces to the hornblende. Orthoclase is also present, chiefly intergrown in crystallographic relation with quartz, forming micropegmatitic patches, which give to portions of the rock very much the appearance of a granophyre.

Quartz occurs almost entirely in micrographic intergrowth with the orthoclase as sharply defined skeleton crystals, often triangular in outline. It is thus of prior consolidation to the felspar with which it is associated, and in thin section is the more distinct from its being entirely unaffected by the agencies which have rendered the felspar almost opaque.

Ilmenite is abundant in irregular grains and skeleton crystals, and is, no doubt, the source of the black 'titaniferous ironsand' which is so plentiful in the locality. Its outline, lustre, and characteristic alteration afford a ready means of identification.

Sphene, of the white variety known as leucoxene, has been abundantly produced by the decomposition of the ilmenite. It does not form definite crystals, but it serves to bring out the internal structure of the ilmenite in a most striking manner, owing to the way in which decomposition has proceeded along the lines of least resistance, related to the crystalline form (hexagonal) of the original mineral.

Other accessories are pyrites and apatite, neither of which is plentiful. The former is easily recognised by its pale brassy colour, as seen by reflected light. The apatite forms slender prisms, longitudinal sections showing the cross-fracture, while transverse ones show the characteristic six-sided form. A colourless mineral with the roughened appearance characteristic of a high refractive index also occurs as a decomposition product of the hornblende. It is almost isotropic, and may be referred to the chlorite group.

Structure.—The texture and structure vary considerably in different parts of the slice. The rock is holocrystalline, but the order of crystallisation of the different minerals is variable and the presence of micropegmatite is distinctive. The other minerals act very much the part of a ground mass toward the horn-

blende, though the appearance of the rock is not strikingly porphyritic, and the general structure is very similar to that of the less basic syenite-porphyries of the Charnwood district in Leicestershire. It points, in fact, to a hyp-abyssal as opposed to a plutonic origin for the rock, which might therefore be classed as a diorite-porphyry or hornblende-porphyrite.

8. *Note on some Anthropods from the Upper Silurian.* *By* MALCOLM LAURIE.

9. *The Copper-bearing Rocks of South Australia.* *By* F. P MENNELL.

The copper ores of Yorke's Peninsula in South Australia were the first metallic minerals worked on the Australian continent. They occur in rocks of Archæan age, which at Moonta and Wallaroo have been subjected to crushing and shearing to such an extent that they present few traces of their original structures, except in the case of a diorite at Wallaroo, which is of a typically plutonic character. Most of the rocks are mylonites, and in some instances have been reduced to a compact flinty type, in which none of the minerals can be recognised with certainty. Where the original constituents have survived they are of a fragmentary character; oligoclase seems to have best resisted the crushing, and orthoclase occasionally remains in lenticles; but the brittle quartz has invariably been reduced to powder. The economic aspect of the examination is of considerable importance, for the mines have several times been shut down when the ore has thinned out owing to doubts as to its permanence. From the character of the rocks it is, however, obvious that they occur in a true 'fissure lode,' and no doubts need be felt as to the continuance of the ore to the limit of workable depths.

10. *Report on the Excavation of the Ossiferous Caves at Uphill, near Weston-super-Mare.*—See Reports, p. 352.

SECTION D.—ZOOLOGY.

PRESIDENT OF THE SECTION.—Professor J. COSSAR EWART, M.D., F.R.S.

THURSDAY, SEPTEMBER 2.

The President delivered the following Address:

The Experimental Study of Variation.

THE study of variation may be said to consist (1) in noting and classifying the differences between parents and their offspring; and (2) in determining by observation and experiment the causes of these differences, especially why only some of them are transmitted to future generations. The facts of variation having been dealt with at considerable length in a recent work by Mr. Bateson, I shall discuss chiefly the causes of variation.

Though for untold ages parents have doubtless observed differences in the form and temperament of their children, and though breeders have long noted unlooked-for traits in their flocks and herds, the systematic study of variation is of very recent date. This is not surprising, for, while the belief in the immutability of species prevailed, there was no special incentive either to collect the facts or inquire into the causes of variation; and since the appearance in 1859 of the 'Origin of Species,' biologists have been mainly occupied in discussing the theory of natural selection. Now that discussions as to the nature and origin of species no longer occupy the chief attention of biologists, variability—the fountain and origin of progressive development—is likely to receive an ever-increasing amount of notice. Strange as it may appear, naturalists at the end of the eighteenth century concerned themselves more with the causes of variation than their successors at the end of the nineteenth. Buffon, who discussed at some length nearly all the great problems that interest naturalists to-day, after considering variation arrived at the conclusion that it was due to the direct action of the environment, and even invented a theory (strangely like Darwin's theory of pangenesis), to explain how somatic were converted into germinal variations. Erasmus Darwin and Lamarck also had views as to the causes of variation. Erasmus Darwin believed variability resulted from the efforts of the individual, new structures being gradually evolved by organisms constantly endeavouring to adapt themselves to their surroundings. Lamarck about the same time endeavoured to prove that changes in the environment produced new needs, which in turn led to the formation of new organs and the modification of old ones, use being especially potent in perfecting the new, disuse in suppressing the old. Both Erasmus Darwin and Lamarck, without attempting, or apparently even seeing the need of, any such explanation as pangenesis offered, assumed that definite acquired modifications were transmitted to the offspring, and they both further assumed that variations occurred not in many but in a single definite direction; hence they had no need to postulate selection. The speculations of Erasmus Darwin and Lamarck having

had little influence, it fell to Charles Darwin to construct new and more lasting foundations for the evolution theory.

Charles Darwin, clearly realising that variation occurs in many different directions, arrived at the far-reaching conclusion that the best adapted varieties are selected by the environment, and thus have a chance of giving rise to new species. Though impressed with the paramount importance of selection, Charles Darwin realised that 'its action absolutely depends on what we in our ignorance call spontaneous or accidental variation.'[1] Darwin, however, concerned himself to the last more with selection than with variation, doubtless because he believed variability sinks to a quite subordinate position when compared with natural selection. As variations stand in very much the same relation to selection as bricks and other formed material stand to the builder, Darwin was perhaps justified in rating so highly the importance of the principle with which his name will ever be intimately associated. Though Darwin considered variability of secondary importance, it may be noted that he did more than any other naturalist to collect the facts of variation, and he, moreover, considered at some length the causes of variation. He regarded with most favour the view 'that variations of all kinds and degrees are directly or indirectly caused by the conditions of life to which each being or more especially its ancestors have been exposed.'[2] Of all the causes which induce variability, he believed excess of food was probably the most powerful.[3] In addition to variations which arise spontaneously in obedience to fixed and immutable laws Darwin believed with Buffon that variations were produced by the direct action of the environment, and with Lamarck by the use and disuse of parts; and he accounted for the inheritance of such variations by his theory of pangenesis. Darwin seems always to have regarded the direct action of the environment and use and disuse as, at the most, subsidiary causes of variation; but Mr. Herbert Spencer and his followers regard 'use-inheritance' as an all-important factor in evolution; while Cope and his followers in America, by a mixture of 'use-inheritance' (Kinetogeneis) and Lamarck's neck-stretching theory (Archæsthetism), apparently see their way to account for the evolution of animals with but little help from natural selection.

Professor Weismann and others, however, have recently given strong reasons for the belief that all variation is the result of changes in the germ-plasm ultimately due to external stimuli, the environment acting directly on unicellular, indirectly on multicellular organism. It is convenient to speak of biologists who believe with Mr. Herbert Spencer in the law of use and disuse (use-inheritance) as Neo-Lamarckians, and of those who with Weismann refuse to accept the doctrine of the transmission of definite acquired characters, and in the case of multicellular organisms the direct influence of the environment as a cause of variation, as Neo-Darwinians. In discussing variability I shall assume that all variations are transmitted by the germ-cells; that the primary cause of variation is always the effect of external influences, such as food, temperature, moisture, &c.; and that 'the origin of a variation is equally independent of selection and amphimixis,'[4] amphimixis being simply the means by which effect is given to differences inherited, and to the differences acquired by the germ-cells during their growth and maturation.

Theoretically the offspring should be an equal blend of the parents and (because of the tendency to reversion) of their respective ancestors. In as far as the offspring depart either in an old or in a new direction from this ideal intermediate condition they may be said to have undergone variation. The more obvious variations consist of a difference in form, size, and colour, in the rate of growth, in the period at which maturity is reached, in the fertility, in the power withstand disease and changes in the surroundings, of differences in temperament

[1] *Animals and Plants*, vol. ii. p. 206.

[2] *Ibid.*, vol. ii. p. 240. Elsewhere he says we are 'driven to the conclusion that in most cases the conditions of life play a subordinate part in causing any particular modification.'

[3] *Ibid.*, vol. ii. p. 282.

[4] Weismann, *The Germ-Plasm* p. 431.

and instincts, and in the aptitude to learn. In the members of a human family there may be great dissimilarity, and the dissimilarity may be even greater in the members of a single brood or litter of domestic animals, especially if the parents belong to slightly different breeds.

Frequently some of the offspring closely resemble the immediate ancestors, while others suggest one or more of the remote ancestors, are nearly intermediate between the parents, or present quite new characters. Similarly seedlings from the same capsule often differ. Can we by way of accounting for these differences only with Darwin say that variations are due to fixed and immutable laws, or at the most subscribe to the assertion of Weismann, that they are 'due to the constant recurrence of slight inequalities of nutrition of the germ-plasm'?[1] Weismann accounts for ordinary variation by saying that the reduction of the germ-plasm during the maturation of the germ-cells is qualitative as well as quantitative, *i.e.*, that the germ-plasm retained in the ovum to form the female pro-nucleus is different from the germ-plasm discharged in the second polar body. He accounts for discontinuous variation and 'sports' by 'the permanent action of uniform changes in nutrition.'[1] These uniform changes in nutrition, by modifying in a constant direction susceptible groups of germ-units (determinants), after a time giving rise to new, it may be pronounced variation. Must we rest satisfied with these assumptions, or is it possible to account for some of the variability met with by, say, differences in the maturity of the parents or of the germ-cells, by the germ-cells having been influenced by interbreeding or intercrossing, or by the soma in which they are lodged having been invigorated by a change of food, or habitat, or deteriorated by unfavourable surroundings or disease? In other words are there valid reasons for believing that the germ-cells are extremely sensitive to changes in their immediate environment, *i.e.*, to modifications of the body, or soma containing them, and that the characters of the offspring depend to a considerable extent on whether the germ-cells have recently undergone rejuvenescence?

Obviously, if the offspring, other things being equal, vary with the age of the parents, the ripeness of the germ-cells and with the bodily welfare, the qualitative division of the nucleus on which Weismann so much relies as an explanation of ordinary variation will prove inadequate.

Is Age a Cause of Variation?

During the course of my experiments on Variation I endeavoured to find an answer to the question, 'Is Age a Cause of Variation?' During development and while nearly all the available nourishment is required for building up the organs and tissues of the body, the germ-cells remain in a state of quiescence. Sooner or later, however, they begin to mature, and eventually in most cases escape from the germ-glands. I find the first germ-cells ripened often prove infertile. When, *e.g.*, pigeons from the same nest are isolated and allowed to breed as soon as mature, they seldom hatch out birds from the first pair of eggs, and though quite vigorous in appearance they may only hatch a single bird from the second pair of eggs. The same result generally follows mating very young but quite unrelated pigeons; but when a young hen bird is mated with a vigorous, well-matured male, or a young male is mated with a vigorous, well-matured female, the eggs generally prove fertile from the first. The germ-cells are, as far as can be determined, structurally perfect from the outset; and that they only fail in vigour is practically proved by the fact that, though the conjugation of germ-cells from two young birds leads to nothing, the conjugation of germ-cells from quite young birds with germ-cells from mature birds generally at once results in offspring.

The following experiments indicate how age may prove a cause of variation. Last autumn I received from Islay two young male blue-rock pigeons which, though bred in captivity, were believed to be as pure as the wild birds of the Islay caves. In February last one of the young blue-rocks, while still immature,

[1] *Germ-Plasm*, . 431,

was placed with an inbred white fantail, the other with an extremely vigorous well-matured black barb. In course of time a pure-white bird was reared by the white fantail, and two dark birds by the black barb. Owing probably to the fantail being inbred and the blue-rock being still barely mature, the young white bird died soon after leaving the nest. No birds were hatched from the second and third pairs of eggs laid by the fantail, but from the fourth pair two birds were hatched which are now nearly full-grown. These young birds are of a darker shade of blue, and look larger and more vigorous than their blue-rock sire. As in the Indian variety of the blue-rock pigeon the croup is blue, and, as in some of the Eastern blue-rocks, the wings are slightly chequered. They, however, only essentially differ from their sire in having four extra feathers in the tail. The first pair of birds hatched by the black barb when they reached maturity early in August might have passed for young barbs with somewhat long beaks. Since the first pair were hatched in March the blue-rock and black barb have reared six other birds. One of the second brood closely resembles the first birds hatched; the other is of a greyish colour, with slightly mottled wings, a long beak, and a tail bar. The birds of the third nest are both of a greyish colour, but have indistinct wing bars as well as a tail bar. Of the fourth pair of young one is greyish like the birds of the third nest, the other is of a dark blue colour with slightly chequered wings, and a head, beak, and bars as in its blue-rock sire. The gradual change from black to dark blue in the blue-rock barb crosses is very remarkable. I can only account for the almost mathematical regularity of the change by supposing it has kept pace with a gradual increase in the vigour or prepotency in the young blue-rock. Eventually the offspring of the blue-rock mated to the black barb, like the offspring of its brother with the white fantail, may be of a slaty blue colour, and otherwise resemble a wild blue-rock pigeon. Many breeders would explain the offspring taking more and more after the sire by the doctrine of Saturation—a doctrine that finds much favour amongst breeders—but as identical results were obtained when young females were mated with well-matured males the saturation explanation falls to the ground.

Like results were obtained by breeding young grey quarter-wild rabbits with an old white Angora buck: the first young were white, the subsequent young were white, grey, and bluish grey. From these results it follows that, when old and young but slightly different members of a variety or species are mated a wonderfully perfect series of intermediate forms is likely to be produced. Amongst wild animals the young males rarely have a chance of breeding with the young females; hence amongst wild animals, owing to age being a cause of variation, a considerable amount of material is doubtless constantly provided for selection, thus affording a variety an additional chance of adapting itself to slight fluctuations in the environment.

In the results obtained by crossing mature, vigorous, and, in some cases, inbred males with barely mature females an explanation may be found why in some families the same features have persisted almost unaltered for many generations; why in his features the squire of to-day sometimes exactly reproduces the lines of his ancestors, as seen in portraits and monumental brasses. It should, however, be borne in mind that highly prepotent forms are capable from the first of so completely controlling the development that they transmit their peculiar traits to all their offspring.

Is Ripeness of the Germ-Cells a Cause of Variation?

While difference in age may sometimes account for the earlier broods and litters resembling one of the parents, it fails to account for the very pronounced variation often found in a single brood or litter, and for much of the dissimilarity between members of the same human family. When a *single* fertilised germ-cell, as occasionally happens, gives rise to twins, they are always identical; hence it may be assumed differences in members of the same family have their source in differences in the germ-cells from which they spring. If the offspring vary with the maturity of the soma it may also vary with the maturity of the germ-cells, or at least with their condition at the moment of conjugation.

Some years ago Mr. H. M. Vernon, when hybridising echinoderms, discovered that 'the characterisics of the hybrid offspring depend directly on the relative degrees of maturity of the sexual products.'[1] Mr. Vernon found subsequently that over-ripe (stale) ova fertilised with fresh sperms gave very different results from fresh ova fertilised with over-ripe (stale) sperms, from which he inferred that over-ripeness (staleness) is a very potent cause of variation.[2]

I find that if a well-matured rabbit doe is prematurely (*i.e.*, some time before ovulation is due) mated with a buck of a different strain, the young take after the sire; when the fertilisation takes place at the usual time, some of the young resemble the buck, some the doe, while some present new characters or reproduce more or less accurately one or more of the ancestors. When, however, the mating is delayed for about thirty hours beyond the normal time, all the young, as a rule, resemble the doe. It may hence be inferred that in mammals, as in echinoderms, the characters of the offspring are related to the condition of the germ-cells at the moment of conjugation, the offspring resulting from the union of equally ripe germ-cells differing from the offspring developed from the conjugation of ripe and unripe germ-cells, and still more from the union of fresh and over-ripe germ-cells. This conclusion may be said to be in harmony with the view expressed by Darwin, that the causes which induce variability probably act 'on the sex elements before impregnation has been effected.'[3] The results already obtained, though far from answering the question why there is often great dissimilarity between members of the same family, may lead to further experiment, and especially to more complete records being kept by breeders. It is unnecessary to point out what a gain it would be were breeders able to regulate, even to a small extent, the characters of the offspring.

Is the Condition of the Soma a Cause of Variation?

There is a considerable amount of evidence in support of the view that changes in any part of the body or soma which affect the general welfare influence the germ-cells. This is but what might be expected if the soma in the metazoa is to the germ-cells what the immediate surroundings are to the protozoa. The soma from the first forms a convenient nidus for the germ-cells, and, when sufficiently old and sufficiently nourished, it provides the stimuli by which the ripening (maturing) of the germ-cells is effected. If in the case of the protozoa variation is due to the direct action of the environment, it may be inferred that in the metazoa variations of the germ-cells result from the direct action of the soma, *i.e.*, from the direct action on the germ-cells of their immediate environment. This, however, is quite a different thing from saying that definite somatic variations are incorporated in the germ-cells (converted into germinal variations) and transmitted to the offspring.

It may first be asked, Does disease, in as far as it reduces the general vigour or interferes with the nutrition of the germ-cells, act as a cause of variation? I recently received a number of blue-rock pigeons from India infected with a blood parasite (Halteridium) not unlike the organism now so generally associated with malaria. In some pigeons the parasites were very few in number, in others they were extremely numerous. The eggs of a pair of these Indian birds with numerous parasites in the blood proved infertile. Eggs from a hen bird with numerous parasites fertilised by a male with few parasites proved fertile, but the young died before ready to leave the nest. An old male Indian bird, however, with comparatively few parasites, mated with a mature half-bred English turbit produced a single bird. The half-bred turbit has reddish wings and shoulders, but is otherwise white. The young bird by the Indian blue-rock is of a reddish colour nearly all over, but in make not unlike the cross-bred turbit hen.

Some time before the second pair of eggs were laid, the parasites had completely disappeared from the Indian bird, and he looked as if he had quite

[1] *Proceedings Royal Society*, vol. lxiii. May 1898.
[2] *Ibid.*, vol. lxv. November 1899.
[3] *Animals and Plants*, vol. ii. p. 259.

recovered from his long journey as well as from the fever. In due time a pair of young were hatched from the second eggs, and as they approached maturity it became more and more evident that they would eventually present all the distinctive points of the wild-rock pigeon.[1] The striking difference between the first bird reared and the birds of the second nest might, however, be due not to the malaria parasites but to the change of habitat.

Against this view, however, is the fact that another Indian bird infected to about the same extent as the mate of the half-bred red turbit counted for little when mated with a second half-bred turbit; while two Indian birds in which extremely few parasites were found at once produced blue-rock-like birds when bred—one with a fantail, the other with a tumbler.

Another possible explanation of the difference between the bird of the first and the birds of the second nest, is that the germ-cells were for a time infected by the minute protozoan Halteridium in very much the same way as the germ-cells of ticks are infected by the parasite of Texas fever. But of this there is no evidence, for even in the half-grown birds hatched by the pure-bred malarious Indian rocks the most careful examination failed to detect any parasites in the blood. In all probability Halteridium can only be conveyed from one pigeon to another by Culex or some other gnat.

These results with pigeons suffering from malaria seem to indicate that the germ-cells are liable to be influenced by fevers and other forms of disease that for the time being diminish the vitality of the parents. Further experiments may show that the germ-cells are influenced in different ways by different diseases.

Sometimes the germ-cells suffer from the direct action of their immediate environment, from disturbance in or around the germ-glands. If, for example, inflammation by the ducts or other channels reaches the germ-glands, the vitality of the germ-cells may be considerably diminished; if serious or prolonged, the germ-cells may be as effectively sterilised as are the bacteria of milk by boiling.

In 1900 two mares produced foals to a bay Arab which had previously suffered from a somewhat serious illness involving the germ-glands. These foals in no way suggest their sire. This year I have three foals by the same Arab after he had quite recovered: one promises to be the image of his sire, and the other two are decidedly Arab-like both in make and action.

While the germ-cells are liable to suffer when the soma is the subject of disease, there is no evidence that they are capable of being so influenced that they transmit definite or particular modifications (unless directly infected with bacteria or other minute organisms); that, *e.g.*, the germ-cells of gouty subjects necessarily give rise to gouty offspring. Doubtless if the germ-cells, because of their unfavourable immediate surroundings, suffer in vigour or vitality, the offspring derived from them are likely to be less vigorous, and hence more likely than their immediate ancestors to suffer from gout and other diseases.

It would be an easy matter to give instances of the offspring varying with the condition or fitness of the parents; but it will suffice if, before discussing intercrossing, I refer to the influence of change of habitat.

Is Change of Habitat a Cause of Variation?

It has long been recognised that a change of surroundings may profoundly influence the reproductive system, in some cases increasing the fertility, in others leading to complete sterility. Exotic plants, sterile it may be at first, often become extremely fertile, and when thoroughly established give rise to new varieties. In the case of mares obtained from Iceland and the south of England sometimes a year elapses before they breed. An Arab-Kathiawar pony which arrived during April from India, proved during the first three months quite sterile, owing, I believe, to loss of vigour on the part of the germ-cells, their vitality being only about one-tenth that of a home-bred hackney pony. But the fertility is apparently greatly impaired by even comparatively slight changes of environment. Lions which breed freely in Dublin seem to be sterile in London, and I heard recently that when bulls are changed from one district to another in the north of

[1] In these young birds the breast and some of the wing feathers are imperfect. Fanciers regard this condition of the feathers as evidence of constitutional weakness.

Ireland the immediate result may be complete sterility. The tendency of some exotic plants to 'sport' after they become acclimatised is doubtless due to the fact that their new habitat is unusually favourable, their general vigour—so essential for new developments—is increased, and, probably because certain groups of germ units are constantly stimulated by the new food available, they give rise abruptly or gradually to new and it may be unexpected characters. No one doubts that the bodily vigour is liable to be impaired by fevers and other diseases, by changes in the habitat, unsuitable food, rapid and unseasonable changes of temperature, and the like; hence it will not be surprising if further investigations prove that changes in the soma, beneficial as well as injurious, are reflected in the germ-cells, and thus indirectly induce variation. Moreover there are excellent reasons for believing that the germ-cells are influenced by seasonable changes, such as moulting in birds and changing the coat in mammals. In the case of pigeons, *e.g.*, the young bred in early summer are, other things being equal, larger and more vigorous, and mature more rapidly, than birds hatched in the late summer or autumn. But however sensitive the germ-cells may be to the changes of their immediate environment, *i.e.*, the soma or body in which they are lodged, there is no evidence whatever that (as Buffon asserted and Darwin thought possible) definite changes of the soma, due to the direct action of the environment, can be imprinted on the germ-cells. By the direct action of the environment—food, temperature, moisture, &c.—the body in whole or in part may be dwarfed, increased, or otherwise modified; but such changes only influence the germ-cells in so far as they lead to modifications in their vigour and nutrition. They may expedite or delay maturity, alter the length of the reproductive period, interfere with the nutrition of the germ-cells, or retard the development of the embryo, but they seem incapable of giving rise to definite structural or functional variations in the offspring.

Intercrossing and Interbreeding as Causes of Variation.

The belief was once common amongst naturalists that variability was wholly due to crossing, and at the present day naturalists and breeders alike agree that intercrossing is a potent cause of variability, and are unanimous in regarding interbreeding as an equally potent means of checking variability. The opinion is also general that intercrossing has a swamping influence; that having brought forth new forms it forthwith proceeds to destroy them. Darwin, when discussing reversion, points out that intercrossing often speedily leads to almost complete reversion to a long-lost ancestor, *i.e.*, to the loss of recently acquired and the reappearance of long-lost characters.[1] When, however, he comes to deal with variability, he states that 'crossing, like any other change in the conditions of life, seems to be an element, probably a potent one, in causing variability,'[2] the offspring of the first generation being generally uniform, but those subsequently produced displaying an almost infinite diversity of character. As to the influence of inbreeding, he says 'close interbreeding, if not carried to an injurious extreme, far from causing variability, tends to fix the character of each breed.'[3]

These statements may be quoted in support of the very common belief that intercrossing is both a potent cause of variation and of reversion; that it produces new varieties one moment and swamps them the next. Whether intercrossing may be regarded as the immediate cause of variation or of reversion (it can hardly be both) depends on what is implied by variation. Obviously, variation may be either progressive or retrogressive, *i.e.*, the offspring may differ from their parents in having quite new characters or in presenting ancestral characters, or in being characterised by traits neither new nor old, due to new combinations of characters already recognised as belonging to the variety or species. When intercrossing results in the restoration of old characters, we have reversion or retrogressive variation; when to new combinations of already existing characters like new combinations in a kaleidoscope, we have new variations of a non-progressive kind,

[1] *Animals and Plants*, vol. i. p. 22.
[2] *Ibid.*, vol. ii. p. 254. [3] *Ibid.*, vol. ii. p. 251.

almost always characterised by more or less reversion; when, however, intercrossing results in the characters of one variety being engrafted on another, or to the appearance of characters quite new to the species, we have progressive variation. Judging from the results I have obtained, intercrossing of two distinct varieties results, as a rule, in the loss of the more striking characters of both parents, *i.e.*, in more or less marked reversion, the extent of the loss generally depending on the difference between the forms crossed. For example, if an owl pigeon is crossed with a pigeon known among fanciers as an archangel, nondescript birds are obtained, which may at once, with a white fantail, give birds almost identical with a blue-rock—the common ancestor of all our breeds of pigeons. Intercrossing, on the other hand, rarely leads to the blending of the unaltered characters of two or more varieties, and it never, so far as I have seen, results in the appearance of characters absolutely new to the species. In a word, the immediate result of intercrossing distinct varieties is, as a rule, more or less marked reversion. But though intercrossing usually results in retrogressive variation, it is *indirectly* an extremely potent cause of progressive variation. This is due to the fact (better realised by botanists than zoologists) that cross-bred offspring (first crosses) are (unless the parents have been enfeebled by interbreeding) endowed with an unusual amount of vigour, *i.e.*, intercrossing is of supreme importance, not only because it leads to the co-mingling of germ-plasms having different tendencies, but also and perhaps chiefly because of its rejuvenating influence. The importance of this rejuvenation is usually at once evident if intercrossing is immediately followed by interbreeding. The persistent interbreeding of closely related forms generally reduces the vigour, and, as Darwin points out, 'far from causing variability, tends to fix the character of each breed';[1] but the intercrossing of first crosses (or of highly vigorous individuals closely related in either the direct or the collateral line) without appreciably weakening the constitution, often results in offspring displaying, to use Darwin's words, 'an almost infinite diversity of character.'[2] The epidemics of variation, so often the outcome of interbreeding first or at least vigorous recently produced crosses, are apparently partly due to the union of individuals having a similar tendency checking reversion, and partly to the vigour acquired by recent intercrossing. This much may be inferred from the fact, that when interbreeding is persisted in the variability dwindles as the vigour ebbs.

Breeders agree with Darwin that first crosses are generally uniform, and that the subsequent offspring usually vary immensely; yet neither breeders nor naturalists seem to have clearly realised that interbreeding at the right moment is the *direct* cause of variation, while intercrossing is, except in very rare cases, at the most an *indirect* cause of variation.

It may be here said that it is impossible to over-estimate the importance of vigour in studying variation. Without vigour, no race or breed can maintain its position; without renewed vigour it is hardly likely to develop new characters. The new vigour, as already explained, may be obtained by intercrossing; but it may also be acquired, especially in plants, by a change of surroundings accompanied by a plentiful supply of suitable food.

With rigid selection the gradual loss of vigour may escape notice, but when selection is suspended, rapid deterioration (from the fancier's standpoint) is the inevitable result. If, *e.g.*, a number of pigeons, good specimens of a distinct breed, are isolated and left unmolested for a few years, they rapidly degenerate, *i.e.*, they lose their show points (be they peaks, frills, ruffs, or metallic tints) and reassume the more fixed ancestral characters. If, however, the less characteristic birds are eliminated, and high-class birds are from time to time introduced from another loft, the vigour and the distinctive traits are indefinitely preserved.

If the age and condition of the soma and the state of ripeness of the germ-cells are potent factors, and especially if vigour counts for much, the difficulties of breeders become intelligible, and the unlikeliness of intercrossing being a direct cause of variation all the more evident. The most that can be expected from

[1] *Animals and Plants*, vol. ii. p. 251. [2] *Ibid.*, vol. ii. p. 254.

intercrossing is the engrafting on one breed of the characters of another. Even this rarely happens, and is only possible when the two breeds are somewhat allied. It is impossible, *e.g.*, to unite in one individual all the points of a fantail and a pouter, or of a fantail and a jacobin; but given healthy, vigorous birds, the points of an owl may be engrafted on a barb. Or to take another example, the black ears, feet, &c., of a Himalaya rabbit may be combined with the characteristic form, long hair, and habits of an Angora. It may be impossible to predict what will happen when intercrossing is resorted to, but if pure-bred members of a distinct variety are experimented with—and it is useless working with either plants or animals of unknown origin—characters not already present in one of the varieties need not be looked for.

But while interbreeding at the right moment may be a cause of progressive variation, at other times it leads to what is perhaps best described as degeneration. When, *e.g.*, very young members of the same brood or litter, or unhealthy, closely related individuals, or quite mature and apparently vigorous but for several generations closely related animals are interbred, the offspring frequently differ from their parents. They are often delicate and highly sensitive, and unable to survive unless provided with highly nutritious food; and though they mature numerous germ-cells they rear but few offspring, and, what is still more striking, they are sometimes either white or all but devoid of pigment. Offspring thus characterised, especially when white or nearly white in colour, *e.g.*, nearly white pheasants, partridges, and woodcock, white specimens of the brown hare, white squirrels, &c., are sometimes regarded as distinct varieties, but when the departure from the normal colour, &c., is the result of close inbreeding, it is better to regard it as a form of degeneration.

In the spring of 1900 I crossed a quarter-wild grey doe rabbit with a closely inbred black-and-white buck. The young obtained varied considerably in colour: to one of her offspring coloured like the sire, the grey doe produced a second litter, all but one decidedly lighter in colour than the sire. Two of the darker members of this litter produced almost white young, and to one of them the original grey doe has recently produced a light-coloured litter consisting of two pure-white specimens, two with only a narrow dorsal band, two fawn-coloured, and one black. Close interbreeding with goats and pigeons yields similar results. Birds on small remote Pacific islands are sometimes marked with irregularly dispersed white patches. These pie-bald birds, like light-coloured pheasants, cream-coloured partridges, and dun-coloured rooks, may also be the victims of close inbreeding.

The Swamping Effects of Intercrossing.

The question 'Are new varieties liable to be swamped by intercrossing?' is perhaps the most important now pressing for an answer from biologists. What would happen, for example, if specimens of all the different breeds of cattle were set free and left unmolested on a large area? Would they some centuries hence be represented by several breeds or by one? Many would answer this question by saying that unless some of them in course of time were isolated by mountains, deserts, or other physical barriers, they would eventually through intercrossing give rise to a single breed. To this question Darwin would, I think, have given a somewhat different answer, for, while admitting 'that isolation is of considerable importance in the production of new species,' he was, on the whole, 'inclined to believe that largeness of area is of more importance.'[1] Unfortunately Darwin nowhere indicates how he supposed new varieties escape being swamped by intercrossing. His silence on this important point is difficult to explain, for during his lifetime the influence of intercrossing in checking progress, except in one direction, was often enough insisted on. Huxley tells us that in his earliest criticisms of the 'Origin' 'he ventured to point out that its logical foundation was insecure so long as experiments in selective breeding had not produced varieties which were more or less infertile.'[2] Later Moritz Wagner and others pointed out the important

[1] *Origin of Species*, p. 104. [2] *Life of Professor Huxley*, p. 170.

part physical isolation had played in the origin of species; and later still Romanes endeavoured to show how the blighting influence of free intercrossing might be overcome by physiological selection, Romanes, like Huxley, believing several varieties might be evolved in the same area if more or less mutually infertile. Evidence of the importance of physical isolation is plentiful enough; but neither has experimental nor selective breeding proved that physiological isolation has been instrumental in arresting the swamping effects of intercrossing. Hence, according to Huxley and others, the foundation of Darwin's doctrine of natural selection must still be regarded as insecure. Is intersterility the only possible means by which new varieties can be saved from premature extinction, from being destroyed before they have a chance of proving their fitness to survive? In other words, are barriers as essential among wild as among domestic animals? It does not seem to have occurred to the biologists who so fully realised the need of isolation, that the old varieties instead of swamping might be swamped by the new, and that several varieties might sometimes be sufficiently exclusive to flourish and eventually give rise to a like number of species in the same area. If on an island two new varieties of sheep appeared sufficiently vigorous, or, as we say, sufficiently prepotent, to swamp all the other varieties—as the ill-favoured lean kine did eat up the fat ones—and yet so exclusive that their cross-bred offspring invariably belonged to the one new variety or the other, for their preservation fences and other barriers would be superfluous.

Is there any evidence that by prepotency the swamping of new varieties is sometimes checked, and that by exclusive inheritance two or more varieties, though mutually fertile, may persist in the same area, occasionally intercrossing with each other, but neither giving up to nor taking from each other any of their distinctive characters? I have in my possession a skewbald Iceland pony that produces richly striped hybrids to a zebra, but skewbald offspring the image of herself in make, colour, and temperament to whole-coloured bay Arab and Shetland ponies. This pony instead of being swamped invariably swamps older breeds. A number of prepotent skewbald ponies, wherever placed, would (especially with the help of preferential mating) in all probability soon give rise to a distinct race such as once existed in the East. What is true of the Equidæ is equally true of other groups. Black hornless Galloway bulls are often so prepotent that their offspring with long-horned brightly coloured Highland heifers readily pass for pure-bred Galloways. The wolf is prepotent over the dog, as the wild rabbit, rat, and mouse are prepotent over their tame relatives. As an instance of prepotency in rabbits, I may give the results of an interbreeding experiment with a grey doe, the granddaughter of a wild rabbit, and an inbred buck richly spotted like a Dalmatian hound. Of six young in the first litter three were like the sire. To one of her sons the grey doe next produced eight young, all richly spotted, and subsequently to one of her spotted grandsons she produced two spotted, two white, and two grey offspring. Similar results are obtained with plants; hybrid orchids, *e.g.*, sometimes reproduce all the characters of one of the parents.

It need hardly be insisted on that if new varieties, well adapted for their environment, are not only sufficiently prepotent to escape being swamped by other varieties, but are also, like the spotted rabbit, able to hand on the prepotency almost unimpaired to a majority of their descendants, progressive development along a definite line will be possible. But of even more importance than prepotency is what for want of a better name may be known as exclusive inheritance. Recently a vigorous mature Indian blue-rock pigeon mated with an inbred and equally mature fantail, hatched and reared two birds, one exactly like a blue-rock, but with fourteen instead of twelve tail feathers; the other characterised by all the points of a high-class fantail, the tail feathers being thirty in number—two fewer than in the fantail parent, but eighteen more than in the blue-rock parent. In this case the blue-rock was the exclusive bird, the fantail having previously produced birds with only sixteen feathers in the tail when mated with an ordinary dovecot pigeon. A still more striking example of exclusive inheritance we have in the crow family. The carrion crow and the hooded crow are so unlike in colour that they were long regarded as two distinct species; now they are said to

be two varieties of the same species. The carrion crow is black all over, but in the hooded crow the breast and back are grey. These two crows cross freely (but for this they would probably still rank as distinct species); but in the crossbred young there is never any blending—they are either black or grey, usually both varieties occurring in the same nest. Similar exclusiveness occurs amongst mammals. When distinct varieties of cats are crossed, some of the young usually resemble one breed, some the other, and the distinctions may persist for several generations. A white crossed with a tabby-coloured Persian cat produced a pair of white and a pair of tabby-coloured young; the two white cats when interbred also produced two white and two tabby-coloured individuals. I find cats are far more exclusive than rabbits: perhaps it is partly for this reason we have so many species and varieties of wild cats, so few species and varieties of wild rabbits. Another very striking instance of exclusiveness we have in the Ancon or 'Otter' sheep common in New England at the end of the eighteenth century. This breed, which was characterised by short crooked legs and a long back like a turnspit dog, descended from a ram-lamb born in Massachusetts in 1791. The offspring of this 'sport' were never intermediate in their characters: they were either like the original Ancon ram or like the breeds, some thirteen in number, with which he was mated. Frequently in the case of twins one was otter-like, the other an ordinary lamb. More remarkable still, the Ancon-like crosses, generation after generation, were as exclusive as their crooked-legged ancestor.

Another familiar example of exclusiveness we have in the peppered moth, a dark variety of which in a few years swamped the older light variety throughout a considerable part of England, and is now extending its range on the Continent. It thus appears that when a new variety is sufficiently prepotent, instead of being swamped it may actually swamp the old-established variety; and that when two or more varieties are sufficiently exclusive they may flourish side by side, and eventually give rise to two or more distinct species.

Prepotency may hence be said to supplement and complete the work of the environment. The environment seems to be mainly concerned in eliminating the unfit; whether any of the survivors persist depends not so much on their surroundings as on whether they are sufficiently prepotent and exclusive to escape being swamped by intercrossing. This way of accounting for progress in one or more directions may prove as inadequate as the one suggested by isolationists, but it has the merit of being more easily tested by experiment. It not only gets rid of the swamping bugbear, but makes it matter of indifference whether (to quote from the President's address at the last Oxford meeting of the Association) 'the advantageously varied bridegroom at the one end of the wood meets the bride, who, by a happy contingency, had been advantageously varied in the same direction, and at the same time, at the other end of the wood.' Further, as a highly prepotent vigorous variety can very well afford to maintain a number of budding organs, it helps us to understand how luminous, electric, and certain other structures were nursed up to the point when they began to count in the struggle for existence.

Doubtful Causes of Variation.

Having indicated how maturity of the soma and of the germ-cells, and how bodily welfare and interbreeding may act as causes of variation, and also how swamping of the new variations may be checked, I shall now refer to certain supposed causes of variation.

Maternal Impressions.

I may begin with the widespread belief that the offspring are capable of being influenced in form, colour, and temperament by maternal impressions—the belief we associate with the skilful shepherd who peeled wands and stuck them up before the fulsome ewes. Muller,[1] more than half a century ago, conclusively argued against the belief in maternal impressions, but the belief still prevails. I know o

[1] *Elements of Physiology*, vol. ii. p. 1405.

two able naturalists who subscribe to the maternal impression doctrine, and it is firmly held by many breeders and by not a few physicians. A writer in a recent number of a quarterly,[1] which circulates widely amongst farmers and stock-keepers, boldly asserts that the existence of impressions which affect progeny (more especially in colour) is a settled fact. This writer supports his case by referring to a highly successful breeder of polled Angus cattle, who considered it necessary to surround his herd 'with a tight black fence in order to keep the females from dropping red calves because they saw the red herds of his neighbours.' Reference is also made by this writer to the belief, common in certain parts of England, that whitewashed byres, regardless of the colour of the parents, produce light-coloured calves; that the colour of foals is often more influenced by the stable companion of the dam than by her own colour or that of the sire; and that even the colour of birds varies with the immediate surroundings, fowls, *e.g.*, however carefully penned, hatching birds resembling in colour the hens they habitually see in a neighbouring run. If maternal impressions thus influence the offspring they must be one of the most effective causes of variation. During the last six years I have bred many hundreds of animals, but the nearest approach to an instance of maternal impressions was a dark pup with a white ring half round the neck, which suggested the white metal collar sometimes worn by his sire. But similar rings round the legs and tail rather discredited the view that the white neck-ring was in any way related to the sire's nickel-plated collar. Telegony was sometimes said to be due to maternal impressions. It was doubtless for this reason that I was urged some years ago to carefully prevent the mares used in my experiments from seeing too much of the zebras. But though numerous foals have been bred from mares stabled with zebras or grazing with richly striped zebra hybrids, not a particle of evidence have I found in support of the maternal impression doctrine. The foals have neither stripes nor upright manes, and do not even attempt to mock the weird barking call of the zebra. Sheep and cattle, goats, rabbits, and guinea-pigs, fowls and pigeons, have simply confirmed the results obtained with horses. This being the case, grooms may very well omit following the practice (considered so essential in Spain during the Middle Ages, and still often religiously observed in England and America) of setting 'before the mares . . . the most goodly beasts' by way of hinting to them the kind of foals they are expected to produce.

The Needs of the Organism as a Cause of Variation.

No recent biologists are perhaps prepared to believe like Lamarck that the wings of birds were developed by their remote ancestors making efforts to fly; that by stretching its toes the otter acquired webbed feet; nor are they prepared to find in our new mammal, the Ocapi, evidence in support of Lamarck's contention that to meet new needs the giraffe by much stretching gradually lengthened his neck. Yet it is difficult sometimes to see any real difference between the beliefs of the new Lamarckians and the old. It is maintained, for example, 'that when a certain functional activity produces a certain change in one generation it will produce it more easily the next,' that, *e.g.*, flounders and their allies by constant efforts generation after generation have dragged the left eye to the right side, while by similar efforts in the turbot and certain other flat fishes the right eye has been shifted to the left side. It is not alleged by Neo-Lamarckians that globe fishes resulted from round fishes blowing themselves out, or that flounders resulted from round fishes generation after generation making efforts to flatten themselves. If by germinal variation and selection flounders were evolved out of round fishes, is it not straining at a gnat and swallowing a camel to refuse to admit that by the same factors the left eye of the flounder has been transferred from the left to the right side of the head? In the flat fishes it is not difficult to imagine how by variation and selection the eyes originally acquired the power of responding to certain external stimuli.

[1] *Bibby's Quarterly*, Autumn Number, 1900, p. 163.

The Direct Action of the Environment and Use-Inheritance as Causes of Variation.

Of the doctrine of the transmission of acquired characters, still so often the subject of discussion, I need say little more than that I have failed to discover any evidence in its favour. Writing in 1876, Darwin says, 'In my opinion the greatest error which I have committed has been not allowing sufficient weight to the direct action of the environment, *i.e.*, food, climate, &c., independently of natural selection.'[1] Darwin not only in his later years reverted to the teaching of Buffon, but, in as far as he continued to believe in the 'inherited effects of use and disuse,' he adopted the views of Erasmus Darwin and Lamarck. While admitting that the direct action of the environment on the soma and use-inheritance are indirect—it may be potent—causes of variation, I do not believe there is any trustworthy evidence in support of the view that definite somatic variations are ever transmitted.

Telegony as a Cause of Variation.

The belief in telegony is less deserving of consideration than the doctrine of the transmission of acquired characters. Nevertheless I perhaps ought to refer to it at greater length, not so much because of its scientific importance, but because it interests all sorts and conditions of men in many different parts of the world. Telegony ('infection of the germ' of older writers) means that not only the immediate parents but also the previous mates (if any) contribute to the characters of the offspring; that, *e.g.*, a mare which had produced foals to, say, 'Ladas' and 'Persimmon' might thereafter give birth to a foal by 'Flying Fox,' to which 'Ladas' and 'Persimmon,' as well as the actual sire, contributed some of their characteristics. Many even think a sire may transmit definite structural characters from one mate to another. If there is such a thing as telegony, if it is possible to blend, without the risks of intercrossing, the characteristics of several individuals or varieties, progressive development would be greatly accelerated. Though the doctrine of 'infection' has probably long formed part of the breeder's creed, it received but little attention from men of science until in 1820 Lord Morton communicated a case of infection to the Royal Society, which in due time was published in the 'Philosophical Transactions.' In this the most credible and best authenticated of all the cases of telegony on record a chestnut mare, after rearing a quagga hybrid, produced to a black Arabian horse three foals of a peculiar bay colour, one of them (a filly) showing more stripes than the quagga hybrid, and, according to the stud groom in charge of 'the colts,' characterised by a mane 'which from the first was short, stiff, and upright.'[2] Darwin, after fully considering Lord Morton's case, came to the conclusion that the chestnut mare had been infected, and this case along with others led him to believe that the first male influenced 'the progeny subsequently borne by the mother to other males.'[3] If the upright zebra-like mane in one of the pure-bred colts and the markings on all three were the result of the chestnut mare having been first mated with a quagga, there is undoubtedly such a thing as telegony, and the presumption is that other mares first mated with a quagga or zebra and then with a black Arabian would give birth to striped offspring with a stiff if not quite upright mane. The evidence that from the first the mane of the filly was short, stiff, and upright is most unsatisfactory. It consists of an allegation by a stud groom. That the mane was upright, as in the quagga and zebra, is *à priori* improbable, (1) because the mane of the quagga hybrid instead of being short and stiff was long and lank enough to arch to one side of the neck; (2) because the mane of zebra hybrids throughout the greater part of the year is so long that it falls to one or it may be both sides of the neck; and (3) because in the Equidæ

[1] *Life and Letters*: Letter to Moritz Wagner.
[2] *Phil. Trans.*, 1820, p. 21.
[3] *Animals and Plants*, vol. ii. pp. 435, 436.

an upright mane is always accompanied by a tail deficient of hairs at the root—in the filly the tail is as perfect as that of her Arab sire. We have still stronger evidence that the allegation of the groom was unfounded from drawings (of the chestnut mare, her three 'colts,' the black Arab, the quagga, and the quagga hybrid) by Agasse, a very reliable animal painter of the early part of last century. In the drawing of the filly the mane is represented as lying to one side, as in Arabs and other well-bred horses. The pictures (now in the Museum of the Royal College of Surgeons, London) were made because the subsequent foals were believed to prove the truth of the 'infection' doctrine. Had the mane of the filly been erect it would hardly have escaped the keen eyes of the artist. But had Agasse by any chance missed this all-important detail, Lord Morton or some of those interested would doubtless have called his attention to the matter. If the mane of an Arab is completely removed early in the spring it is stiff, and upright in the autumn, but hanging to one side close to the neck in the following summer. When the whole circumstances are taken into consideration, there seems to me no escape from the conclusion that the mane of the filly was upright when seen by Lord Morton in August 1820, and lying to one side when painted by Agasse the following summer, because it had been regularly cropped or at least hogged some months before Lord Morton's visit. But whatever be the explanation of the want of agreement between the mane as seen by Lord Morton and as depicted by Agasse, it will, I think, be admitted that the evidence afforded by the mane of the filly is hardly sufficient to establish the truth of the doctrine of telegony. Of still less value is the evidence afforded by the make, coat-colour, and markings which were apparently too indistinct to deserve the name of stripes. The colts were decidedly Arab-like, of a bay colour marked more or less 'in a darker tint.' Judging from Agasse's drawings they closely resemble Arab-Indian crosses; they are, in fact, in make very like the Arab-Kathiawar horse already referred to. I have seen a bay Highland cob with as many stripes as Lord Morton's colts, and pure-bred Arabs of a dun colour with stripes on the neck and far more distinct leg bars than those depicted by Agasse. I believe the colts owed their stripes and colour, not to 'infection' of their dam by her previous mate the quagga, but to reversion. It is quite possible the black Arabian horse was of mixed origin; that the chestnut mare was crossbred is admitted. As in the west of Ireland the offspring of black and chestnut ponies are sometimes of a decidedly dun colour, it is not surprising that the black Arab and the half-bred chestnut had bay offspring. Neither are the stripes surprising. I recently ascertained that the chestnut mare was presented to Lord Morton (while serving with his regiment in India) by one of his officers—Mr. Boswell of Deeside, Aberdeenshire—and that she was most likely a cross between an Arab and a country-bred pony. In Kathiawar the ponies when pure-bred are of a rufous grey colour and more or less richly striped. If in the chestnut mare there was any Kathiawar or even any native pony blood its offspring to a black sire might have been expected to be of a dun colour and striped. In a word, there is no reason for assuming that the foals would have been less striped if the chestnut mare had been mated with the black Arab first and the quagga afterwards.

By way of testing the truth of the 'infection' doctrine I started, in 1895, a number of experiments, and especially arranged to repeat as accurately as possible, what is commonly called Lord Morton's experiment. Since then twelve mares, after producing sixteen zebra hybrids, a mule, and a hinny, have had an opportunity of supporting the telegony hypothesis by giving birth to twenty-two pure-bred foals.

During the same period Baron de Parana of Brazil has bred at least six zebra hybrids, and some of the dams of these hybrids subsequently produced ordinary foals. Further, Baron de Parana has for a number of years been engaged in crossing cattle and in watching the results obtained in several mule-breeding establishments, where from 400 to 1,000 brood mares are kept. As in these establishments the mares breed mules and horses alternately—two or three mules and then a horse foal—there has been carried on for some years, under the observation of Baron de Parana, a telegony experiment on a gigantic scale.

The single hybrid bred by Lord Morton had extremely few stripes, and only

in a remote way suggested a member of the zebra family. All my hybrids, like those bred in Brazil, have more stripes than their zebra sire, and in some of them the bands are nearly as conspicuous as in some of the zebras, thus proving that both the mares (which varied in colour and breed) and the two zebra stallions used were well adapted for the experiment. The results of my experiments, not only with the Equidæ but also with other domestic quadrupeds and birds, all point to the conclusion that there is no such thing as telegony, and the same conclusion has been independently arrived at by Baron de Parana in Brazil. Believers in telegony—they are numerous in America, India, and Australasia, as well as in England—almost always say of the many experiments recently made with a view to giving 'infection' a chance of showing itself, that they have only yielded negative results, and they generally add, it is impossible to prove a negative. After carefully considering all the more striking so-called cases of 'infection,' I have no hesitation in saying that there is no satisfactory evidence that there has ever been, either in the human family or amongst domestic animals, a single instance of 'infection.'

I have in a hurried and imperfect manner indicated that we are not likely to find either in maternal impressions, the direct action of the environment, use-inheritance, or telegony a true cause of variation. I have endeavoured to point out that, instead of simply stating that variation is due to the constant recurrence of slight inequalities of nutrition of the germ-cells, we may with some confidence assert that differences in the age, vigour, and health of the parents and differences in the ripeness of the germ-cells are potent causes of variation.

I have also endeavoured to prove that intercrossing, though a *direct* cause of retrogressive variation, is only an *indirect* cause of progressive variation, while interbreeding (in-and-in-breeding) at the right moment is a cause of progressive variation.

Further, I have discussed at some length the swamping effects of intercrossing, chiefly with the object of showing (1) that progress in a single direction is probably often due to new varieties swamping old, it may be long-established, varieties; and (2) that several varieties may be sufficiently exclusive to flourish side by side in the same area, and eventually (partly owing to their aloofness, *i.e.*, to differential mating) give rise to several new species.

I have only now to add that I was mainly led to select 'The Experimental Study of Variation' as the subject of my address that I might indirectly indicate that the time had come when a well equipped institute should be provided for biological and other experiments.

The following Papers and Reports were read:—

1. *The Pelvic Cavity of the Porpoise* (Phocæna communis) *as a guide to the determination of a Sacral Region in Cetacea. By* DAVID HEPBURN, *M.D., F.R.S.E., Lecturer on Regional Anatomy, and* DAVID WATERSTON, *M.A., M.D., F.R.S.E., Demonstrator of Anatomy, University of Edinburgh.*

Among Cetacea the absence of hind limbs renders it difficult to determine from external examination where the trunk of the body ends and the tail begins, but upon the skeleton the presence of chevrons enables us to differentiate the caudal from the so-called lumbar vertebræ. No means of subdividing the lumbar vertebræ into lumbar and sacral sets having hitherto been suggested, the authors are of opinion that a key to such subdivision may be found in a study of the vertebral relations of the pelvic cavity. They have determined the existence of a true pelvic cavity in the common porpoise. This cavity corresponds to five præ-caudal vertebræ, and its anterior end is opposite the 29th vertebra behind the skull. The authors have examined the vertebral columns of a number of four-footed mammals and find that the first segment of the fused sacrum varies in position from the 27th to the 31st vertebra behind the skull. Among Cetacea they find that

while allowing five præ-caudal vertebræ for a sacral series, there is much variability regarding the position of the first sacral segment. Thus, among certain Mystacoceti, it would occur from the 27th to the 31st vertebra behind the skull, but in Balænoptera sibbaldii at the 33rd or 34th. Among toothed whales (Denticeti) the variability is much greater, especially among Delphinidæ, not only in different species, but even in different specimens of the same species and in different sexes, for the first sacral vertebra may be situated from the 27th to the 43rd vertebra behind the skull.

Notwithstanding these differences, the position of the pelvic organs indicates that they are due rather to variation in the number of dorsal and true lumbar vertebræ than to increase in the length of the sacral region. Therefore, from the position of the pelvic organs and the presence of a peritoneal cavity (pelvic) in Cetacea, and also the common occurrence of five vertebræ in the sacrum of quadrupedal mammals, the authors believe that among Cetacea five præ-caudal vertebræ might fairly be classified as sacral, or, conversely, that the sacral series of vertebræ might be reckoned from the inlet of the peritoneal pelvic cavity to the first of the chevron-bearing or caudal vertebræ.

2. *The Relationships of the Premaxilla in Bears.*

By RICHARD J. ANDERSON, *M.D., Professor of Natural History, Galway.*

The premaxilla presents many features of interest because of its relations to other bones in the same animal, and to the same bone in other animals, also because of the peculiar position which was assigned to it in the vertebrate theory of the skull.

This bone in the bears articulates with the frontal, and differs in this respect from the position of the bone in other carnivora. The following summary represents the facts in the species examined:—

Ursus pyrenæus.—The distance from the alveolar margin of the premaxilla to the nasal in the middle line is $2\frac{3}{8}$ inches. The naso-premaxillary suture is 3 inches in length. The premaxilla 1 inch wide below by $3\frac{1}{4}$ inches in length. The nasal is 3 inches and the maxilla $3\frac{3}{4}$ inches. The maxilla is thus shut out from the nasals.

Ursus labiatus.—The length of the skull here is 1 foot and the premaxilla 4 inches. The premaxilla is nearly $\frac{1}{4}$ inch across at the lower end of the nasals. The measurement from the incisor alveolar margin to the lower border of the nasals is $2\frac{1}{4}$ inches. The naso-premaxillary articulation is 2 inches in length.

Ursus arctos.—The length of the skull is 1 foot 2 inches; nasals, $3\frac{1}{2}$ inches by $\frac{1}{2}$ inch broad; premaxilla, $4\frac{1}{4}$ inches long by $\frac{3}{8}$ inch broad. This may be compared with the last. The distance of the alveolar margin from the lower border of the nasals is $2\frac{3}{4}$ inches. It is $1\frac{3}{4}$ inch from the nasal edge to the point of articulation with the frontal. The naso-premaxillary suture is $2\frac{1}{8}$ inches. Brown bear has a naso-maxillary suture (Owen).

The premaxilla of the Himalayan bear reaches further up and back than in Ursus arctos and U. labiatus. Alveolar margin to nasal is $2\frac{1}{4}$ inches; naso-premaxillary suture, $1\frac{3}{8}$ inch; premaxillary maxillary suture, $3\frac{3}{8}$ inches.

Heliarctos has a skull 1 foot in length. The nasal is 3 inches and premaxillary 4 inches long. The alveolar margin is $2\frac{1}{8}$ inches distant from the nasals. The naso-premaxillary suture $1\frac{1}{2}$ inch.

Ursus maritimus has nasals 4 inches long and premaxillæ 5 inches. The nasals appear to reach higher than usual. The distance of the lower border of nasals from the alveolus is $3\frac{1}{4}$ inches; the naso-premaxillary margin is $1\frac{7}{8}$ inch.

The fen bear, an ancient variety of Ursus arctos, which is sometimes found in Irish bogs, has a premaxillary maxillary suture $3\frac{1}{2}$ inches long, and naso-premaxillary $1\frac{3}{4}$ inch (a little less than in U. maritimus); the alveolar margin to nasal, $2\frac{3}{4}$ inches. This and other specimens were kindly placed at my disposal in the Kildare Street Museum, Dublin.

It is thus observable that, whilst in some specimens (*e.g.*, the Himalayan and white bear) the nasals appear to be proportionally longer (reach higher up), there appears to be tolerable uniformity.

Comparing Kindred Genera.—Herpestes has an arrangement similar to the bears. The specimens examined belonged to the College of Surgeons' Museum. The marten has premaxillæ that nearly touch the frontals. In *Genetta tigrina* these bones approach, and in the specimen examined the premaxilla of the left side touches the frontal. The premaxillæ in *Procyon lotor* reach almost to the frontal. *Mellivora capensis* has a naso-maxillary suture three-eighths of an inch long.

The Canidæ approach the Ursidæ in only some of their species in the character of the connections of the premaxilla. Canis aureus has a naso-maxillary suture one-eighth of an inch long, or less. The tips of the frontals and premaxillæ approach in the fox, whilst in a St. Bernard dog 3 inches may be interposed between the maxillaries and frontals. Hence we see that in the Canidæ there is less uniformity than in the Ursidæ.

The common otter (Lutra vulgaris) and the sea otter do not show any articulated frontals and premaxillæ. The grey seal, common seal, and walrus show no resemblance to the bears.

The whales, Mesoplodon, Orca, and the dolphins, on the other hand, have greatly elongated premaxillæ with greatly reduced nasals, whilst in the Sirenia enormous development of the former corresponds with abortion of the latter.

The great development of the premaxillæ in rodents and elephants, as in the dugong, seems to be associated with the large incisor teeth, but the hyrax is more like the Macropus in this regard. The premaxillæ in lemurs, monkeys, and ant-eaters are short and attached by their upper ends to the nasals; they are not much concerned in the elongation of the skull in the latter group. The skull of Myrmecophaga jubata, 14 inches long, has nasals 7 inches, but premaxillæ very short and set perpendicularly to the nasals, the external inferior angle of which they touch. The apparent separation of a portion of the frontal part of the premaxilla appears to be the result of a wormian ossification such as is seen in the gorilla. The 'accessory premaxilla' found in relation with the premaxilla in monotremes seems to have no representative in mammals (Van Bammelen).[1] It seems, therefore, that—

(1) The Ursidæ have the premaxilla usually articulating with the frontal. The suture may occupy a higher level in some forms.

(2) That in the Procyon, marten, and Genetta the bones nearly touch.

(3) Some Canidæ resemble the bears in having the maxillæ almost separated from the nasals.

(4) That the otters and common seals differ from the bears in this regard, as also does the walrus.

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3. *Report on the Migration of Birds in Great Britain and Ireland.* See Reports, p. 364.

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4. *Report on the Occupation of a Table at the Zoological Station, Naples.* See Reports, p. 354.

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5. *Report on the Occupation of a Table at the Marine Biological Laboratory, Plymouth.*— See Reports, p. 376.

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6. *Report on the 'Index Animalium.'*—See Reports, p. 362.

[1] Meckel, Owen, Turner, De Blainville, &c.

7. *Report on the Plankton and Physical Conditions of the English Channel.*—See Reports, p. 353.

8. *Eleventh Report on the Zoology of the Sandwich Islands.* See Reports, p. 352.

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9. *Report on the Coral Reefs of the Indian Region.*—See Reports, p. 363.

FRIDAY, SEPTEMBER 13.

The following Papers were read:—

1. *The Coral Islands of the Maldives.*[1] *By* J. STANLEY GARDINER, *M.A.*

The Maldive Archipelago to the south-west of Ceylon is made up of a large series of comparatively shallow banks separated from one another by channels of about 170 fathoms in depth. They extend north and south as a chain, double in the centre, for 550 miles. All are covered with coral reefs arising to the surface. Some banks have on their circumferences the single ring-shaped reefs of perfect atolls, while others are studded with numbers of small isolated reefs many of which are of circular form with shallow lagoons. The two classes of bank merge into each other, and the changes taking place at the present day are such that the atolls may naturally be supposed to have arisen by the fusion of the smaller reefs.

All land in the Maldive group owes its origin directly or indirectly to elevation and in most atolls is very markedly washing away. Everything points to a state of rest at the present day. The atoll reefs are perfecting themselves on all sides, and their passages are closing up. The reefs, however, are not broadening, but to a certain point narrow as they become more perfect. The central basins of atollons are everywhere coming into free communication with the lagoons of the atolls. There is no trace whatever of the filling in of the lagoons; indeed, such evidence as was found pointed on the contrary to their further widening and deepening, and to the gradual destruction of the shoals and lands within their encircling reefs. The Maldive group certainly marks the existence of an ancient land area, but the changes going on are not consistent with the view that the reefs were built up on the subsidence of the land. The various reefs appear rather to have grown up separately on slight elevations of a common plateau at a depth of about 150 fathoms, while the plateau itself seems to have been formed by the washing away of the original land by wave and current actions.

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2. *On a Method for Recording Local Faunas.* *By* EDWARD J. BLES, *B.A.*, *B.Sc.*

It is evident that faunological work is the basis upon which zoological investigations of all kinds are founded. The important questions connected with the study of environment—since the biological no less than the physical environments of any particular organism must be taken into account—depend for their solution on an accurate and complete knowledge of the associated fauna and flora. There are unlimited opportunities for work on this fascinating subject at

[1] For a full account of these islands see *The Fauna and Geography of the Maldives and Laccadives*, Camb. Univ. Press, vol. i., part 1 (October 15, 1901) and part 2 (in the press).

our own doors, and for this reason alone, though there are many others equally weighty, the compilation of our own local faunas is most desirable.

The scheme proposed[1] consists in the formation by natural history societies of card or slip catalogues of species on a similar plan to the library catalogues first devised in the United States. To facilitate reference each card would be filled in on a uniform plan with the name of genus and species say at the top left-hand corner, and columns or spaces for locality, date of capture, recorder, means used to identify the specimens, remarks, in fact any data considered desirable. The number of cards or slips assigned to each species need not be limited, but would depend on the number of localities and other details thought necessary to be recorded. The slips might vary in colour to indicate which entries are taken from literature and which are due to personal observation, to denote extinct species or those of economic importance, or to make any useful distinction. The slips would be arranged on files on a definite system and with the use of the well-known devices for dividing into groups.

An extremely desirable feature of the scheme would be that each slip should be represented and the species authenticated by a specimen in the local natural history museum. The slip could easily bear a reference to the particular specimen in the collection, and as the catalogue became filled up it might be placed in some local public institution where it could at any time be utilised by naturalists.

In this manner all the information collected by the members of local societies could be brought together, from whatever source obtained; and there is no reason why the fauna of a given district should not in course of time be completed in the same sense as the British flora of flowering plants has been completed.

The district need not necessarily supply the specialists for all the groups of animals. Specialists at a distance would in many cases be pleased to work out collections carefully furnished with localities, &c., and thus supply the data for filling up slips.

This scheme not only allows of the widest co-operation by bringing to a focus both the results of systematic work and that of a more desultory nature, but also favours the co-ordination of faunistic observation, since overlapping of work would at once become apparent, and the gaps caused by neglect of certain groups of animals would declare themselves, and thus attention and interest in filling up the deficiencies would be invited.

Another advantage is the fact that the scheme can be started at any time by filling up any number of slips, however small, and that then all additions whether made singly or in quantity will at once find their proper places and by accumulation eventually bring the list nearer and nearer to completion.

The present time is ripe for the commencement of this work. There seems to be no reason why it should be deferred, and a strong argument in favour of the assertion is given by so highly competent a body of naturalists, the German zoologists, having committed themselves, and no doubt wisely, to that great undertaking 'Das Tierreich.'

It is, I think, desirable to consider whether some body of English naturalists with the necessary authority, say the Committee of the Conference of Delegates to the British Association, should not see to it that the local Natural History Societies of the United Kingdom adopt some such plan of record upon one and the same system. Such a body of naturalists could draw up the most generally convenient and useful form of slip and impress upon the Societies the value of cataloguing by its use in a uniform manner the fauna of the whole country. Having the method provided would perhaps encourage some societies to take up the work.

Political divisions and areas surrounding large towns are not often of zoological value. The results obtained by this larger scheme would eventually have to be rearranged according to the natural features of the country. By making the slips all uniform the final rearrangement would be enormously facilitated, if not reduced to the minimum of labour.

[1] First suggested by myself to the Cambridge Entomological and Natural History Society in a paper read on April 26, 1901.

In concluding, I must acknowledge the assistance I have obtained by discussing the local scheme with the members of the executive committee of the Cambridge Entomological and Natural History Society, which intends commencing a fauna of Cambridgeshire on the lines suggested.

3. *Some Notes on the Behaviour of young Gulls artificially and naturally hatched.*—See Reports, p. 378.

4. *The Theory of 'Germinal Selection' in Relation to the Facts of Inheritance.*[1] *By* Professor J. ARTHUR THOMSON, *M.A.*

The aim of this communication was to test Weismann's theory of germinal selection by using it as an interpretation of some important facts of inheritance. The author gave a brief abstract of the theory. It is an extension in the applicability of the general idea of natural selection. To 'superorganic' selection, ordinary 'individual' or 'personal' selection, Roux's 'histonal' or intra-organismal selection, Weismann has added the idea of a struggle among the determinants within the germ—germinal selection.

The author indicated the importance of a form of struggle between Roux's histonal selection and Weismann's germinal selection, namely, the struggle between gametes or potential gametes, *e.g.*, between young ova, between sperms, even between ova and sperms. A vivid realisation of this visible struggle, and the sometimes discriminate selection which it implies, may lead naturally to an appreciation of germinal selection which deals with the wholly invisible.

The following extension of Weismann's idea of germinal selection was proposed as logical and necessary:—Just as there are three types of individual struggle, (1) between kindred organisms, (2) between organisms not akin, and (3) between organisms and the so-called inanimate environment; so there may be (1) struggle between determinants of the same character, (2) struggle between different kinds of determinants (Weismann), and (3) struggle between all or any of the determinants and the somatic or more external environment.

After stating the advantages of Weismann's theory and possible objections, the author proceeded to test it in relation to various facts of inheritance:—(1) The frequently anomalous and unpredictable nature of the results of a pairing even when the pedigrees are well known; (2) the phenomena of preponderant and exclusive inheritance; (3) some of the results of the 'Penycuik experiments' on the importance of the relative ripeness of the gametes; (4) some well-established cases of true reversion; (5) the supposed greater stability and dominance of the phylogenetically older characters; (6) inbreeding; (7) different modes of variation, including De Vries' mutation; and (8) the indirect effect which exogenous changes may have on the germ plasm.

The author's conclusion was that Weismann's theory of 'germinal selection' justifies itself provisionally as a formula unifying a large number of otherwise unrelated facts of inheritance.

5. *The Heterotypical Division in the Maturation Phases of the Sexual Cells. By* THOMAS H. BRYCE, *M.A., M.D.*

Of the features of Heterotypical Mitosis the one generally selected as distinctive is the ring form of the chromosomes, each ring being considered to arise from the incomplete separation of the two products of the longitudinal cleavage of a primary chromatin rod. The manner in which these ring chromosomes are resolved has been variously interpreted. For the purposes of this note it will suffice that three interpretations be summarised, thus:—

[1] The paper will be included in the author's work on *Heredity* (John Murray, 1902).

1st. The rings are drawn out on the spindle, and break into **V**-shaped daughter chromosomes.

In the anaphase in some cases each daughter **V** is found again divided into two **V**'s, and the secondary cleavage is held to be longitudinal. In other cases the **V**'s break at their apices into double rods by a cleavage held to be transverse. No solution of this contradiction is found along this line.

2nd. The rings are doubled up on themselves and are resolved by being reopened along the plane of the bend. There is a second longitudinal cleavage seen, but it is only *apparent*. Variation in the form of the chromosomes is explained by variation in the degree of the cleavage, by variation in the insertion of the traction fibres, and by different degrees of bending of the rings (Farmer and Moore).

3rd. There is a *real* second longitudinal cleavage which appears in the metaphase, and is completed in the anaphase of the first Mitosis. Thus daughter and granddaughter chromosomes are formed in the course of the first Mitosis, the second Mitosis merely distributing the granddaughter chromosomes (Gregoire, Strasburger, 1900).

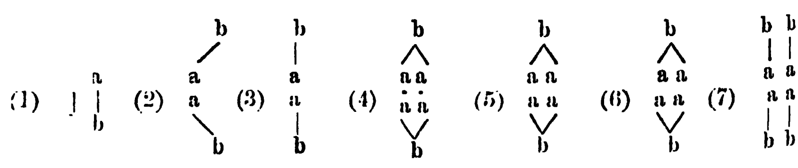
This view of the heterotype serves in Strasburger's latest work to explain all the phenomena in plants—differences arising only from the manner in which the double rod prophase figures are placed on the spindle. In the animal series only Carnoy and Le Brun and Janssens adopt the idea of the simultaneous double longitudinal cleavage in Triton.

When true tetrads occur the first Mitosis is not strictly heterotypical in character. In recent studies of the phases in Echinus I have found typical tetradal bodies, never rings, yet the first Mitosis is heterotypical in character, and my results show that part at least of the problem of reduction lies *not*, as has been held, in the determination of the *origin*, but rather in the *fate* of the tetrads.

Thus in Echinus esculentus there are sixteen tetrads, each consisting of a pair of slightly curved bilobed rods lying back to back. The tetrads come to lie radially on the first polar spindle. Each is opened out like a hinge from within outwards, while at the same time a second longitudinal cleavage is taking place from without inwards. Lozenge-shaped figures are produced: these elongate greatly and ultimately break at the equator into two **V**'s, which again in the anaphase break at their apex to form two short bilobed rods lying back to back. This apical splitting is the completion of the second longitudinal splitting. These bilobed rods pass unchanged into the second Mitosis, arrange themselves radially on the spindle, are opened out and separated from one another as the granddaughter chromosomes, formed in the anaphase of the 1st Mitosis by the second longitudinal cleavage. In the second polar body each remains as a short bilobed rod, but in the ovum each greatly elongates into a sharply bent **V**. This change in the size of the chromosomes is important as indicating the relaxation from the very condensed condition of the chromatin rods characteristic of the divisions with the reduced number of chromosomes.

Applying the hypothesis of 'Pseudo-reduction' (Häcker and Rückert) to the facts observed each half of the tetrad might be considered to represent two chromosomes united end to end by the omission of the last segmentation of the chromatin thread. Through all the phases the fate of each lobe or sphere of the tetradal body can be traced. The facts can be expressed in the usual formula, thus, for each of the sixteen tetrads:—

1st Mitosis.



2nd Mitosis.

(1)	(2)	(3)	(4)	(5)
a a | |• b b	b / a a \\ b	b | a a | b	b | a b | a	b \\ 2nd polar a , body

Thus reduction would be only apparent throughout.

I have been unable to determine whether the tetrads arise by the omission of the last stage of the segmentation of the chromatin thread or by conjugation, but as each element is twice longitudinally divided in the heterotypical division, the chromatin is equally distributed between the ovum and the polar bodies, and there is no question of a reducing division or of unequal distribution of 'qualities.'

Whether the idea of 'pseudo-reduction' as represented above be accepted or not, the essential feature is a reduction in bulk merely. The chromatin substance is, in Echinus esculentus, packed in the maturation phases into sixteen instead of thirty-two chromosomes. In view of the fact—whether the hypothesis of the 'Individuality of the Chromosomes' be accepted or not—that the *same* number of chromosomes always emerge from a dividing nucleus as entered it, this reduction in bulk of the chromatin may very well be a *secondary* character acquired to maintain the number of chromosomes constant after the union of the nuclei in fertilisation.

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6. *The Fishes of the Coats Arctic Expedition. By* W. S. Bruce, *F.R.S.G.S., Heriot Research Fellow of Edinburgh University.*

The author gave an account of the fishes collected by the Coats Arctic Expedition in 1898, with which he sailed as zoologist. Mr. Andrew Coats, of Paisley, resolved to undertake a voyage to the Arctic regions in 1898 in his yacht 'Blencathra,' now 'Pandora.' The 'Blencathra' had previously been used for Arctic exploration by Sir Allen Young and Mr. Popham. On board there was the essential apparatus of an expedition, fitted out for oceanographical research, viz., Lucas sounding machine, thermometers, water-bottles, trawls, traps, and townets. On the return of the expedition Mr. Coats contributed a considerable sum, which enabled the author to sort and classify the collection preparatory to a detailed examination, which he has since been making by the help of the George Heriot Research Fellowship, Edinburgh University. So far the careful examination of the fishes constitutes the greater part of the work. There are fully 400 fishes in the collection, about sixty of which are adult specimens belonging to eleven species. The author gave an account of these species, which he has examined in great detail. The collection is the first of any importance in the Barents Sea, and is useful in bridging over the gaps in the series obtained by Payer in 1874, and the author in 1896 97 in Franz Josef Land, and those of the more recent Russian expeditions in 1898, 1899, and 1900 of the Murman coast of Arctic Russia.

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7. *The Fauna of Franz Josef Land. By* William S. Bruce *F.R.S.G.S. Heriot Research Fellow of Edinburgh University.*

The author gave a preliminary account of the collections of the Jackson-Harmsworth Polar Expedition to Franz Josef Land in 1896 97, when he accompanied that expedition as zoologist. The author was able to secure over 600 species of animals, by far the largest ever obtained by any previous polar expedition, and added about 500 species to the previously known fauna of Franz Josef Land. He

made most of the collections in shallow water, near the shore, at Cape Flora; but also in deep water, as, for instance, in the farthest north station, in 81° N., where he dredged in 250 fathoms. Marine invertebrates form by far the greatest part of the collections. Three new mammals were recorded, viz., the Fin-back Whale, Narwhal, and Floe Rat (the smallest known seal). Also five new birds, viz., the Lapland Bunting, Shore Lark, Turnstone, Bonaparte's Sandpiper, Purple Sandpiper. Among invertebrates the crustacean collection is the most remarkable, 173 species being obtained. This remarkable number is greater than all the previously known species of animals of Franz Josef Land. Of these the author pointed out that there were ten species new to science, and that the striking feature was the recurrence in the high north latitude of species which inhabit British shores. Other classes of animals were also richly represented in the collection.

8. *On the Mechanism of the Frog's Tongue.* *By* Prof. MARCUS HARTOG *and* NEVIL MASKELYNE.

SATURDAY, SEPTEMBER 14.

The Section did not meet.

MONDAY, SEPTEMBER 16.

The following Papers were read:—

1. *Dimorphism in Foraminifera.* *By* J. J. LISTER, *F.R.S.*

2. *The Relation of Binary Fission and Conjugation to Variation.* *By* J. Y. SIMPSON, *D.Sc.*

It is a long-standing generalisation that binary fission is mere duplication; that the products of the process are exactly alike. The use of this generalisation in theory is obvious. In binary fission we do not look for variation; accordingly we are left with an excellent rationale of conjugation, and so, finally, of sexual reproduction, viz., a means to produce variation in the interests of evolution.

A possible objection to the belief that binary fission is duplication may be raised on *a priori* grounds. Conjugation would still appear to be unconfirmed in the case of the Amœboidea. If, then, there was no variation through binary fission, there could not have been evolution.

The contention is not that there is *always* variation in binary fission, which is probable, but perhaps impossible to prove. Where it was not quantitative, it might yet be qualitative. In many cases quantitative variation cannot be established under a less magnification than 625.

The species specially examined in this connection were Paramecium caudatum and Stylonichia pustulata. The points to which hitherto examination has been restricted are: (*a*) the general outline; (*b*) the total length; (*c*) the extremest breadth; (*d*) the distance between the two contractile vacuoles (Paramecium); (*e*) the length of the middle caudal bristle (Stylonichia).

In all these five points I found variation ranging in (*b*) from 1 to 20μ, in (*c*) from 1 to 20μ, in (*d*) from 1 to 20μ, for Paramecium; and for Stylonichia in (*b*) from 1 to 60μ, in (*c*) from 1 to 20μ, and in (*e*) from 1 to 10μ. The variation in (*a*) for either form is demonstrated by microphotographs. The general corre-

spondence in the figures is due to extreme cases. The following are the statistics relating to the points b, c, d in μ for ten pair of Paramecium :—

	b	c	d
First pair	165...160	45...40	100...95
Second pair . . .	180...190	60...55	105...100
Third pair	200...193	45...50	110...110
Fourth pair . . .	140...150	40...45	80...85
Fifth pair	180...190	50...55	105...110
Sixth pair	230...220	60...50	110...105
Seventh pair . . .	260...240	85...90	125...115
Eighth pair . . .	280...260	80...65	145...125
Ninth pair . . .	260...240	80...70	115...105
Tenth pair . . .	250...230	75...95	120...110

The following statistics, also in μ, relate to the points b, c, d for five pair of Stylonichia pustulata :—

		c	d
First pair .	240...230	120...110	35...30
Second pair	210...180	110...90	40...30
Third pair	230...240	110...100	40...40
Fourth pair	230...245	115...110	35...40
Fifth pair	230...220	90...110	35...30

The measurements are for full-grown forms, but the microphotographs of Paramecium show variation at different stages of development. The variation was traced into the succeeding generation.

From the fact that there is variation in binary fission we get additional reason for holding with Engelmann, Maupas, and Bütschli, as against Gruber, that the vegetative phase of the life of the ciliata is primary, and we are enabled to see in conjugation simply a device whereby the waste involved in that process can be refunded.

3. *On a new Form of Luminous Organ.* *By* W. E. Hoyle, *M.A.*

4. *Notes on Some Bornean Insects.* *By* R. Shelford, *M.A.*

Orthoptera.—Two species of aquatic cockroaches—*Epilampra* sp. and a Panæsthiid—were found at the base of a waterfall on Mount Matang, Sarawak. All the specimens were immature, but adult forms have been discovered by Mr. Annandale in the Malay Peninsula; the females are apterous. These cockroaches swim and dive well, but are soon drowned if prevented from rising to the surface to breathe, agreeing in this characteristic with most adult aquatic insects. When at rest the body of the cockroach is almost entirely submerged, the tip of the abdomen alone projecting above the surface of the water; the abdomen moves gently up and down, and every 30-40 seconds a bubble of air issues from the prothoracic spiracle on each side. Apparently the terminal spiracles are purely inspiratory in function and the prothoracic expiratory.

The eggs of the stick-insects of the genera *Necrosia*, *Marmessoidea*, and *Agondasoidea* are not seed-like as are the eggs of other genera; twenty or thirty only are laid, and these are stuck in close-set rows on the leaves of the food-plant, not dropped promiscuously on the ground. The eggs are long and somewhat flattened ovals, white or cream-coloured, with a delicate network of black pigment over the upper surface; there is no capitulum. The young hatch out in 10-14

days, and the empty egg-shell is left adhering to the leaf to which it was originally fastened.

It is noteworthy that Phasmidæ, notwithstanding their wonderful protective resemblance to sticks and leaves, are the staple form of diet of Trogons.

Neuroptera.—A remarkable Agrionid nymph, apparently allied to *Euphæa*, occurred with the aquatic cockroaches. The last segment bears three pear-shaped processes, and a pair of tracheal tufts protruded from and withdrew into the cloacal opening in a rapid systole and diastole; the tufts open to the exterior on each side of the anus, and each arises from the seven or eight branches, into which the two dorsal tracheal trunks break up on either side of the rectum: they are not connected in any way with the rectum. The pear-shaped processes are hollow, and their cavities communicate by the narrow lumina of their stalks with the general body cavity: they are lined with epithelium and contain blood, but are not supplied with tracheæ. It is possible that these structures are highly modified caudal gills, which now function as blood reservoirs, the flow of blood to and from which may assist in the diastole and systole of the tracheal tufts.

Hymenoptera.—The habits of the bees of the genus *Koptosthosoma* were investigated. In the females of these bees there is a chamber at the base of the abdomen containing numerous Acari; experiments with and dissections of the nymphs showed that the Acari do not enter this special abdominal chamber until the final stage in the development of the bee is reached. The nests of these bees and also those of the genus *Xylocopa*, which are hollowed out in softwood posts and dead saplings, simply swarm with Acari.

Coleoptera.—The remarkable *Mormolyce phyllodes* excavates in Polypori fungi a large lenticular chamber, entered by a narrow slit between the fungus and the bark of the tree to which the fungus is attached; the chamber usually contains a few larvæ in various stages of development. The larvæ present no features calling for special remark, being typically Carabid in appearance; the nymph is provided with the foliaceous expansions characteristic of the adult. A male and female Mormolyce are invariably found in close propinquity to the nest, keeping a close guard over it.

The metamorphoses of two Lycid beetles—*Lycostomus melanurus* and *Calochromus melanurus*—were investigated. The larvæ of both species are found beneath the bark of trees, and they feed on the larvæ of other insects which frequent the same situations. They are conspicuously coloured with black and orange, and experiments have shown that they are as distasteful to insectivorous vertebrates as the adult forms. The full-grown larva of *L. melanurus* measures 25 millimetres. The head is minute and can be completely withdrawn into the first thoracic segment: it is incomplete behind, and does not enclose the brain; the antennæ are two-jointed and retractile into a sheath; a simple ocellus is situated at the base. The suctorial mandibles are sickle-shaped and enclosed in a thin chitinous sheath; the maxillæ consist each of a single four-jointed palp; the labium is a triangular plate with two three-jointed palps. The body is somewhat flattened dorso-ventrally, each segment except the last bears a spiracle; the last segment bears a ventral sucker formed by the everted lips of the rectum. A simple hook represents the tarsus. The larva of *Calochromus melanurus* agrees in many points with the above description; the segments of the body bear short lateral processes with a spiracle at the base of each: these processes are not jointed as in the Malacodermatous larva from New Britain, figured and described by Dr. Sharp ('Zool. Results Willey Exped.: Insects').

Some other Malacoderm larvæ of considerable size (50-80 mm.) were frequently met with, but their life-histories were not traced; in fact these larvæ have long been a complete puzzle to entomologists, since no adults of corresponding sizes are known. The external features of one form have recently been described by Bourgeois ('Bull. Soc. Ent. France,' 1899, pp. 58-63); the head is extremely like that of the Lycid larvæ noted above, and in other points of its anatomy it agrees with those forms; the cuticle is remarkable, being composed of columnar cells with small nuclei: the inner and outer ends of these cells are covered with a thin sheathing of chitin. In another form, with a pair of phos-

phorescent organs in the penultimate segment of the abdomen, the cuticle is glandular.

Lepidoptera.—An interesting example of protective resemblance was furnished by a small Geometer larva which was found feeding on the budding inflorescence of a spiræa-like plant. The larva was pale green in colour and provided with pairs of spine-like processes on the fourth to the eighth and on the eleventh segment; to each of these spines was attached by a delicate secretion of glutinous silk a string of buds of the inflorescence on which the larvæ fed. As these buds withered and turned brown they were cast off and renewed by fresh green ones. The larva did not move about much, but even when it did it was well-nigh indistinguishable from its food-plant. The pupa, which was enclosed in a silken cocoon covered with green buds, was unfortunately destroyed by ants, and no other specimen was obtained.

Diptera.—Some larvæ closely resembling *Vermileo* were discovered on Mount Penrissen, Sarawak, at a considerable altitude. The larvæ formed pitfalls in sand, after the manner of ant-lions. Their habits have been described elsewhere.

A larva, apparently allied to *Microdon*, was found in some numbers under the sheathing leaves of a Caryota palm: it was remarkably slug-like in appearance, showing no signs of segmentation. The upper surface of the body was highly convex, and from the posterior end protruded a short median tube at the base of which was situated a spiracle; the ventral surface was flat and transversely wrinkled; there were no legs or pseudopods: the chitinous head was completely retractile. At the time of pupation the larval skin became strongly chitinised, forming a puparium inside which the further transformation took place.

All the aquatic dipterous larvæ obtained were closely allied to, if not identical with, such well-known European forms as *Corethra, Chironomus, Tanypus, Eristalis, Stratiomys,* &c.[1]

5. *Zebras and Zebra Hybrids.* *By* Prof. J. Cossar Ewart, *M.D., F.R.S.*

6. *On* Echinonema grayi, *a large Nematode from the Perivisceral Cavity of the Sea-urchin.* *By* James F. Gemmill, *M.A., M.D.*

The author exhibited some specimens of a large nematode from the perivisceral cavity of the sea-urchin and gave an account of their occurrence and anatomy.

Females. Body elongated, 600–1,500 mm. in length; 2–4 mm. in breadth; white or semitransparent, tapering at both ends, the posterior end being slightly blunter and curved in a half-circle. A delicate cuticular hook at both ends. Mouth and anus entirely absent; the whole body covered by a delicate cuticle, and the body wall thrown into a series of shallow transverse folds along either side.

Hypodermis, a single layer of nucleated cells; muscular system, a single layer of cells beneath hypodermis, arranged in somewhat irregular longitudinal rows along the ventral third of the body wall, and arranged less markedly in transverse rows on the dorsal two-thirds of the body wall. Excretory system of canals absent. Nervous system, a thickening of the hypodermis at head end, not continued backwards into longitudinal cords. Alimentary canal apparently a mass of spongy reticular tissue, with nuclei and protoplasmic masses at intervals, with an irregular lumen ending blindly at either extremity. Ovary single, greatly elongated; development internal, with total unequal segmentation, followed by a modified form of gastrulation.

Males.—Much smaller, 50–200 mm. in length, with tail coiled characteristically in a spiral, with two equal spicules close to posterior extremity.

This nematode seems to have hitherto escaped notice, except for a mention by A. E. Shipley,[2] whose specimen did not allow him to investigate its structure.

[1] Some of the above noted insects will later form the subject of special memoirs.
[2] *Q.J.M.S.*, 1900, p. 281.

The author means to publish a fuller account of the worm elsewhere, and proposes to name it *Echinonema grayi*.

7. *Exhibition of Abnormal Specimens of Nephrops.* *By* F. H. Marshall.

8. *Exhibition of Microscopic Preparations of Mammalian Hairs.* *By* F. H. Marshall.

TUESDAY, SEPTEMBER 17.

The following Papers were read:—

1. *The Fauna of an Atoll.* *By* C. Forster Cooper.

The island of Hololué is a large wooded sand bank placed at the southern end of the eastern reef of Malé atoll; it is in no place raised more than three feet above high-tide marks. It shows signs of having once been much larger, and of having formerly included the small island of Gadu, now some way to the south. The reefs on the two sides of the island differ from one another in some respects. The eastern and seaward reef is much broader than the western or lagoon reef, and is divided up into three zones, the reef flat, boulder zone, and boat channel, the latter being again subdivided into three zones by the nature of its inhabitants.

On the western side the boat channel is narrower, and corresponds to the middle zone of the boat channel on the east side; the reef on this side is more rich than the other. It was found generally that species were often confined to some particular zone; that where free sand was much washed about by the action of water animals could not and did not flourish. The absence of all seaweeds was also noticeable.

In the lagoon the bottom was found to consist either of sand or mud, the mud usually being deposited in the centre of the lagoon, where the currents lost their orce.

Reef-building corals were never found on the bottom of the lagoon, but only on the slopes of reefs.

The reefs were certainly not extending inwards towards the lagoon, but may perhaps be extending seawards to some small degree.

2. *The Land Crustaceans of a Coral Island.* *By* L. A. Borradaile, *M.A.*, *Lecturer in Natural Sciences at Selwyn College, Cambridge.*

The island in which the species and their habits were observed was the atoll of Minikoi in the Indian Ocean.

The following species of Crustaceans are found on land in Minikoi:—

Crabs:—1. *Ocypode ceratophthalma*, greyish-green in colour, and frequenting the lagoon shore, where it lives in spiral burrows below extreme high-water mark.

2. *Ocypode cordimana*, chocolate-brown in colour, and living in horizontal burrows on land above extreme high-water mark.

3. *Geograpsus grayi*, black and white in colour, running about actively in open spaces.

4. *Geograpsus crinipes*, orange-yellow in colour, and living near freshwater tanks and pools.

5. *Geograpsus longitarsis* var. *minikoiensis*, and 6, *Metasesarma rousseauxi*, dull greenish in colour, living under timber, stones, &c.

Hermit Crabs (Soldier Crabs).—7. *Cœnobita rugosus*, grey or lilac in colour, of small size, and numerous along the shore.

8. *Cœnobita perlatus*, scarlet and white in colour, of middle size, and also found chiefly near the shore.

9. *Cœnobita clypeatus*, purple in colour, of large size, and found in the jungle.

Slaters (Isopods):—10. *Cubaris murinus*, and 11, *Philoscia* sp., woodlice.

12. *Ligia exotica*, lives on the shore.

Land crustaceans, which are the dominant group in a coral island, are of importance in the economy of the island:

i. As scavengers.
ii. In the destruction and disintegration of fruits.
iii. In the distribution of seeds.
iv. In the same manner as earthworms by their burrowing.
v. As enemies of various animals.
vi. Occasionally as food for other animals.
vii. Possibly in the fertilisation of flowers.
viii. Probably in many other ways as yet unknown.

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3. *On the Anatomy of the Larval Polypterus.* *By* J. S. Budgett, *M.A., Trinity College, Cambridge.*

The material for this paper is furnished by a single example of a larval Polypterus, obtained in the Gambia in 1900.

The larva measures 30 mm. in length, and is in the condition when the cartilaginous skeleton has reached its highest development and ossification is about to commence.

The structure of the pectoral fins at this stage affords a strong argument in favour of the view that the Crossopterygian fin is derived from the uniserial type of fin and not from the biserial archipterygium. The suspension of the jaws is in a primitively hyostylic condition, while the hyomandibular cartilage carries a segmented rod of cartilage forming the axis of the root of the external gill.

The vertebral cartilages resemble in their mode of formation those of Lepidosteans and Teleosteans but, in addition to neural and hæmal cartilages to each segment, there are distinct lateral cartilages. The hæmal cartilages give rise to the ventral ribs, which are thus shown to be homologous with the ribs of other Ganoids and Teleosteans, while the lateral cartilages give rise to the transverse processes and lateral ribs, which are homologous with those of Elasmobranchs, Amphibians, and Amniota.

The oviducts are formed by the folding off of a portion of the body cavity into which open a number of nephrostomes, and are thus shown to be of a nature quite different from true Müllerian ducts; there is some evidence that the corresponding duct in the male is homologous with the longitudinal canal of the testicular network in those forms which have vasa efferentia passing to the kidneys, while the vasa efferentia themselves are modified nephrostomes. The head kidney is a very large organ lying between the foremost dorso-lateral and ventro-lateral muscles far from the middle line: it consists of the much coiled anterior end of the archinephric duct, and ends opposite a rather small glomus lying close to the aorta, in the pronephric chamber, which is apparently without a funnel, passing to the general body cavity.

The structure of this larva confirms the belief that Polypterus is an extremely generalised creature showing affinities with three great divisions of Ichthyopsida, Teleostei, Elasmobranchi, and Amphibia.

4. *The Origin of the Paired Limbs of Vertebrates.* *By* J. Graham Kerr.

The author gave a short account of his hypothesis as to the phylogenetic origin of the paired limbs of vertebrates. He passed in review the two current

hypotheses—that of Gegenbaur and that of Balfour, Thacher, and Mivart. Attention was drawn to the complete absence of intermediate stages between gill septum and limb, and also to the *à priori* improbability of a gill septum such as we know in the lower fishes, firmly fixed and flush with the surface, developing into a motor organ. It was pointed out, however, that the numerous advocates of the Gegenbaur view had managed to accumulate a large mass of evidence bearing upon one particular phase of the question, and which consisted of facts pointing to an extensive backward migration of the paired limbs having taken place from somewhere in the neighbourhood of the branchial region.

The lateral fold view had at first the advantage of resting upon a more certain foundation of anatomical fact—upon the fact discovered by Balfour that in the young torpedo the two limbs are for a time connected by a continuous ridge of epiblast—that in this form the paired limbs develop in precisely the way in which the theory supposes them to have developed during phylogeny. Modern research has, however, shown that this longitudinal ridge of epiblast does not appear at all in the less specialised Selachians; even in Torpedo the ridge appears secondarily, and its appearance at all is probably a quite secondary phenomenon associated with the secondary extension of the paired fins along the sides of the body in the adult. Embryology as it is known to-day does not furnish the same foundation for such a theory of limb formation as it appeared to do at an earlier period.

The anatomical resemblances between paired and unpaired fins were touched upon, and it was suggested that such resemblances are probably due to homoplasy.

Attention was now drawn to the fact that in the relations to one another of muscles, skeleton, and viscera in the lower vertebrates there was expressed an admirable mechanical arrangement for lateral flexure of the body. Properly co-ordinated lateral flexures provided a powerful means of locomotion through fluid, a method used by all the lower vertebrates. It was difficult to believe that either a gill septum or a lateral fold could aid to any appreciable extent this primitive method of swimming; the probability was that in its incipient stages a limb derived in such a way must act rather as a hindrance.

The author was of the view that the paired limbs were not at first swimming organs at all, but that they were developed in correlation with movement about a solid stratum. With a solid *point d'appui* even a very small movable projection would be of use in propelling the creature forward. The question was, Did such projections of the body wall exist in the lower vertebrates which might have by evolution become developed into paired limbs? He considered that the most primitive groups of Gnathostomata were the Selachians, the Crossopterygians, the Dipnoans, and the Urodele amphibians. In three out of the four groups there occurred during development true external gills, projections of mesoblast covered with epiblast sticking out from the visceral arches (Mandibular—'Balancer' of Urodeles; Hyoid—Crossopterygians; Branchial Arches I.-III.—Urodeles, *Lepidosiren, Protopterus*; Branchial Arch IV.—*Lepidosiren, Protopterus*). In the Selachians their absence was correlated with the presence of the enormous highly vascular yolk-sac, which made the persistence of any other dermal respiratory organ of early life quite unnecessary. The true external gills were supposed by some to be larval organs independently developed, but further knowledge of their identical relations and development made it impossible to accept any other view than that they were truly homologous structures inherited from a remote ancestor.

The structures in question are provided with elaborate muscular arrangements; in a live Dipnoan or Urodelan larva they are seen to be every now and then sharply flicked back; they are, in fact, though mainly respiratory, potentially motor in function. In Urodeles the corresponding structure on the mandibular arch has lost its respiratory and taken on a purely supporting function.

The author concluded that in these serially arranged potentially motor organs of the lower vertebrates were to be recognised organs homodynamous with the structures which had given rise to the paired limbs; the limb-girdles he followed Gegenbaur in regarding as modified visceral arches. The earliest stage of the

purely motor appendage was probably a simple styliform structure resembling the balancing organ of the Urodele or the limb of *Lepidosiren*, and from this *stylopterygium* had been derived along two divergent lines of evolution—the archipterygium and ichthyopterygium on the one hand and the cheiropterygium on the other.

Finally the author remarked that this hypothesis had the advantage of explaining just as well as did the Gegenbaur hypothesis the traces of backward migration of the limbs; and in regard to the only serious objection to the view—the absence of a cartilaginous skeleton in external gills—he pointed out that this objection, already weakened by the presence of a cartilaginous axis in the barbels of *Xenopus* had now been minimised by the description by Budgett of a rod of cartilage projecting into the base of the external gill in the young *Polypterus*.

5. *The Story of Malaria.* *By* Ronald Ross, *F.R.C.S.*, *F.R.S.*

Interesting nature of the story. Incorrect versions propagated.

Endemic nature and paludal connection of malarial disease give rise to the hypothesis of a telluric miasm. Absence of any scientific proof. Negative experiments of Calandruccio and others.

The first fact—discovery of the malarial pigment, called melanin, by Frerichs, Virchow, and Meckel in 1849–51.

Invention of the *Bacillus malariæ* by Crudeli, Marchiafava, and other Roman writers. Circumstantial details. The whole thing a fabrication.

The second fact—recognition of the melanin-bearing parasite by Laveran, 1880. He describes all forms of the parasite. Predatory Italian efforts.

The researches of Laveran and Golgi concerning the life-history of the parasites within the body. Similar parasites found in birds by Danilewsky. Certain forms of the parasites, now known as gametocytes, cannot be explained. Erroneous degeneration theory of Grassi and Bignami.

Efforts to find the parasite free in nature. Grassi discovers it in a fresh-water amœba—another fabrication. The mosquito hypothesis of King, Laveran, Koch, Manson, Bignami, and others. All formed independently, and are partly right and partly wrong.

I show that the so-called flagella emanating from the gametocytes are living bodies. Sacharoff proves them to contain chromatin. MacCallum demonstrates their true nature.

My attempts to cultivate the parasites of mosquitoes, 1895–97. Failure with 'grey' and 'brindled' mosquitoes (*Culex*). Final discovery of the 'pigmented cells' in 'dappled-winged' mosquitoes (*Anopheles*) in 1897 practically solves the problem.

Whole life-history of the parasites in mosquitoes determined by my experiments on the development of the parasites of birds in *Culex fatigans* in 1898. In association with Annett and Austen I find the similar development of the human parasites in dappled-winged mosquitoes in Sierra Leone, and study the habits of these insects, 1899.

Koch confirms MacCallum's observations, studies the early history of the zygotes, confirms my work (1898), and finds the frequency of infection in native children (1899). Similar studies of Daniels. Great value of their labours. Excellent researches of Christophers, Stephens, Nuttall, Ziemann, Van der Scheer, Rüge, Fernside, and many others. Crucial experiment of Manson in 1900.

After the publication of my work of 1898 Bignami, Bastianelli, and Grassi detect the genus of my 'dappled-winged' mosquitoes from my description, and find, in similar insects in Italy, the development of the parasites described by me. They pretend that their efforts were original. They add no new facts of fundamental importance. Unreliable and predatory nature of their work, especially of that of B. Grassi. Letters from Charles, Laveran, and Koch.

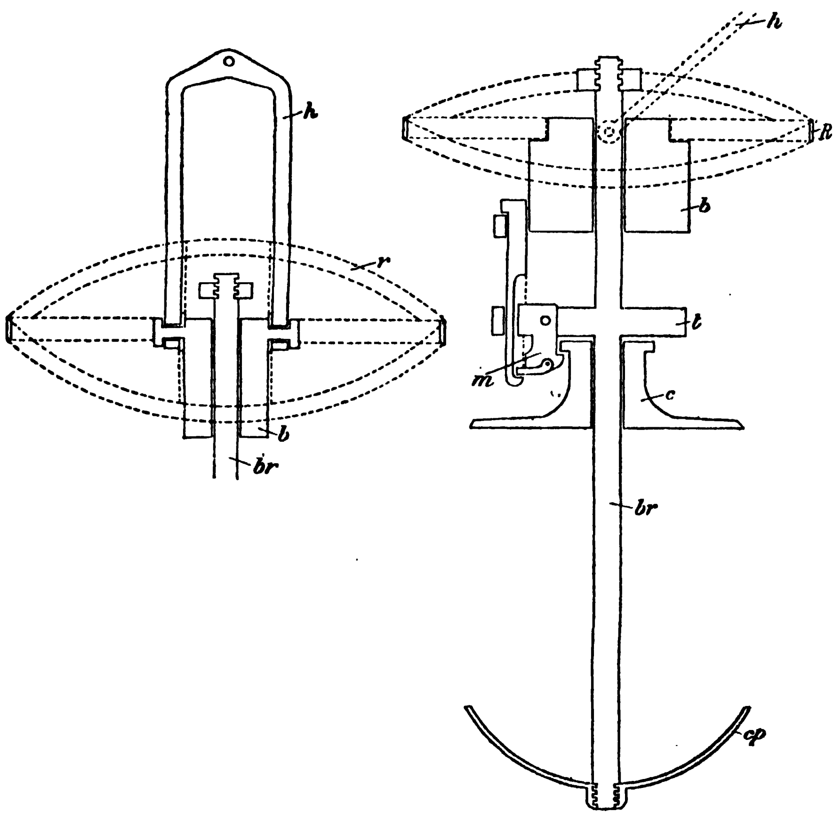
Excellent histories of Mannaberg, Thayer, and Nuttall.

The prevention of malaria and other mosquito-borne diseases. Punkahs, mosquito-nets, wire gauze, and quinine. Segregation. Koch's method. Necessity for ridding towns of mosquitoes. Experiments now in progress in Sierra Leone and Lagos.

6. *Exhibition of Photographs of Fossils in the La Plata Museum. By* Dr. FRANCISCO P. MORENO.

A New Sounding and Ground-collecting Apparatus. By Professor G. GILSON, *of Louvain.*

Side view, showing method of suspension. Front view, showing mechanism.



h, handle suspending block *b*; *b*, cast-iron block; *br*, steel bar; *cp*, cup; *c*, cover; *R*, ring keeping apparatus in an oblique position when lying down on the bottom. This ring is attached to the block *b* and moves with it; *m*, mechanism intended to release the cover *c* when the apparatus is hauled up, and not before that.

The cam seen at the lower part falls as soon as the cup *cp* strikes the bottom, the block *b* sliding down then to the table *t*. This cam is fixed to a flat iron piece with a catch on its right side to suspend the cover *c*. The upper part of this piece is engaged, on the left side, in a groove cut in the vertical rod. When the block *b* is lifted up, the cam not being in place, the end of the groove catches, and the cover *c* is released by the swinging of the flat piece.

This apparatus has been used for some time in the course of certain researches which have been carried on in the North Sea. The task of a complete biological survey of the Belgian coast having been entrusted to the author by his Government, he soon felt the want of a handy ground-collecting instrument. Several of the existing models, among which a few were of the boring-tube type, were tried. Some worked rather well, but, although very heavy, they would only supply a small quantity of sediment. Others gave good results on soft muddy bottom, but no result at all on the sometimes very hard sands of the coast. None of them was found to answer adequately for the particular desiderata of the work, a bulky sample of all kinds of sediments being required. The author then set to work and constructed the very simple apparatus exhibited, which, although a mere embryo rather roughly set up, has done such good service as to induce him to call to it the attention of those engaged in oceanographic study.

It belongs to the cup type of sounding machine, the earliest idea of a ground-collecting apparatus. The cup, however, has been provided with several additional devices which give the whole quite a peculiar character. The most important of these is an iron cover, exactly fitting the cup, and intended to prevent its contents from being washed away. A very simple mechanism keeps this cover lifted up as long as the cup is cutting into the soil. As soon as the cup touches the bottom a little cam falls down, and is unlatched. Later on, when the apparatus is finally hauled up, but not before it takes a vertical position again, the same mechanism releases the cover and allows it to fall and close the cup.

The construction of the apparatus is given in the figure.

One of the most characteristic features of the instrument is that the rope is not connected directly to the iron bar that bears the cup, but to a square block of cast iron through which the bar freely plays up and down.

When a hard ground is reached, the men in charge take care to give the rope a few short pulls in order to make the cup bite into it. If under such circumstances the instrument was allowed to lie flat on the ground it might empty itself after each pull. The ring attached to the iron block is intended to keep the apparatus in an oblique position, thus causing the cup to cut into the soil by its edge, and to gradually fill up, no matter in what direction it may happen to tumble down.

When full the cup contains about six pounds of sand. The whole construction is very simple. There is no piece in it that any blacksmith or ship engineer could not easily repair or even make anew in case of a breakdown; a quality which anyone engaged in exploration would certainly wish all his instruments to possess.

The author has tried this sounding machine in shallow waters only; but there is little doubt that it would work well on the soft ooze of the deep sea. If necessary a system of lost-weight mechanism could easily be devised and connected to it.

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8. *Exhibition of a New Orienting Apparatus for the Cambridge Microtome.* *By* James Rankin.

SECTION E.—GEOGRAPHY.

PRESIDENT OF THE SECTION—HUGH ROBERT MILL, D.Sc., LL.D., F.R.S.E., F.R.G.S.

THURSDAY, SEPTEMBER 11.

The President delivered the following Address:—

ON RESEARCH IN GEOGRAPHICAL SCIENCE.

Introductory.

THE annual reassembling of friends and fellow-workers in the old re-visited towns, and the annual accession of new lovers of science, furnish a unique opportunity for a survey of the advances made in each department, a fitting occasion also for remembering those who have finished their work and can aid our deliberations only by the memory of their example.

Apart from our more intimate losses in the death of many distinguished geographers and devoted workers, the period since our last meeting has been for all a year of mourning. The passing of the nineteenth century was almost like the death of a friend, and it is still difficult to realise that the century which we had been so long in the habit of associating with everything new and great and progressive has itself become part of the past. Few coincidences have been more striking than the almost simultaneous close of that unparalleled reign which gave a name to the Era including all that was best and most characteristic of the century. The death of Queen Victoria carried so keen a sense of personal loss into every heart that few attempts have been made to show how vast a portion of the stream of time—measured by progress—intervened between the terminal dates of her life. Think for a moment of the splendid advances in the one small department of geographical exploration during the late Queen's reign, the multitude of landmarks which have been crowned by the great name of Victoria—of the Earth's most southerly land and its most northerly sea, of the largest lake and most majestic waterfall of Africa, the loftiest lake of Asia, the highest peak in New Guinea, the widest desert and most populous colony in Australia, and of the two thriving seaports on either side of the North Pacific which couple together the British Dominions of western America and eastern Asia.

What could be more appropriate in this first meeting after the close of such a century and of such a reign than to pass in brief but appreciative review the advances of geography during those hundred or those sixty-five years? One thing in my opinion is more appropriate than to dwell on past triumphs or to regret past greatness, and that is to survey our present position and look ahead. In the first year of a new century and of a new reign we are reminded that we have a future to face and that the world is before us, and I propose to seize this opportunity in order to speak of the science of geography as it is now understood and especially to urge the importance of the more systematic pursuit of geographical research henceforward.

Geography in the Universities.

The prospect of immediate expansion in many British universities seems at last likely to afford more than one opportunity of wiping out the old disgrace of the neglect of geographical science in the accredited seats of learning. Already Oxford has a well-manned School of Geography, and Cambridge has a Reader in Geography. The reconstituted University of London occupies the best position in the world for creating a chair of geographical research, situated as it is in the very centre of the comings and goings of all mankind, and in touch with the most complete geographical library and map-collection in existence. The new University of Birmingham may, it is hoped, prove better than its promises, and may perhaps after all provide some more adequate treatment of geography than its proposed partition amongst the professors of half a dozen special subjects, all of them concerned in geography, it is true, but none of them individually, nor all of them collectively, capable of embodying that co-ordination of parts into a harmonious unity which gives to geography its power as a mental discipline and its value for practical application. But England in all that pertains to higher education is still a poor country, and the will to do well is hampered by the grinning demon of poverty. Here, on the other side of the Border, we are in a different atmosphere. The wave of the magician's wand in the hands of Andrew Carnegie has brought wealth that last year would have been deemed fabulous to the ancient universities in Scotland, and it will be a disgrace to our country if this splendid generosity does not result in the establishment of one or more fully endowed and completely equipped chairs of geography.

There may still be some people who view geography as the concern only of soldiers and sailors, adventurous travellers, and perhaps of elementary teachers. Exploration is undoubtedly the first duty of geographers, but it is a duty which has been well done, the nineteenth century having left us only one problem of the first magnitude. This is the exploration of the polar regions, and even here the twentieth century clamours for new methods.

The Antarctic Expeditions.

This year has seen the long-hoped-for Antarctic expeditions set out on their great quest, a quest not only of new lands in the southern ice-world but of scientific information regarding all the conditions of that vast unknown region. Two expeditions have been planned in Great Britain and Germany with a complete interchange of information regarding equipment and methods of work. Provision has been made for simultaneous magnetic and meteorological observations, and in some instances for the use of instruments of identical construction, and all possibility of any unseemly rivalry in striving for the childish distinction of getting farthest south has been obviated by the friendly understanding that the British ship shall explore the already fairly known Ross quadrant, where it is pretty sure that extensive and accessible land will favour exploration by sledges, while the Germans have chosen the entirely unknown area of the Enderby quadrant which no ice-protected steamer has yet attempted to penetrate, and where they enter a region of potential discovery before they cross the Antarctic Circle.

The British expedition is equipped on the good old plan that produced such fine results in the days of Cook and Ross; it is manned by sailors of the Royal Navy and is under the command of a gallant naval officer, though, unlike the earlier vessels, the 'Discovery' is not herself a naval ship. As in the days of Cook the naval officers are assisted in their non-professional work by several young and promising scientific men, two of whom have already had experience of work in the polar regions. These have the great advantage of the counsel and help of Mr. George Murray of the British Museum, who goes as far as Melbourne in the position of Director of the Scientific Staff.

No one who has seen the zeal and unflagging enthusiasm with which Sir

Clements Markham has organised the expedition can hesitate to accord to him in fullest measure the credit for its successful inauguration. And no one who has seen the quiet and good-humoured determination of the commander, Commander R. F. Scott, in overcoming many irritating preliminary difficulties, can doubt his fitness to undertake the heavy responsibilities of the voyage. I am sure that he will be a worthy successor to Cook, Ross, Franklin, Nares, and all the other officers who have made their names and the name of the British Navy famous in Polar service. The second in command, Lieutenant Armitage, R.N.R., has had several years of Arctic experience, and amongst the crew there are some old whalers whose knowledge of the ways of sea-ice should prove of value. The ship and her equipment are unique; it is no exaggeration to say that she is the best-found and most comfortable vessel which has ever left our shores on a voyage of discovery.

The German expedition has been more boldly planned than ours. It is new and experimental all through, as befits a young nation in its first exuberant efforts in a new field. If some people suppose that it may have made mistakes that our expedition has avoided; these, at least, are new mistakes from which new lessons are to be learned. If risks must be run—and we of the twentieth century are, I trust, no more timid of incurring risks than our predecessors of the nineteenth, or the eighteenth, or even the seventeenth—it is good that they should be new risks. To scientific men in Germany it appears natural and reasonable that a man of science should be the head of a scientific expedition; and that a geographer should lead a geographical expedition. Many British men of science sympathise in this view. Dr. Erich von Drygalski, one of the professors of Geography in the University of Berlin, has been entrusted with the command to which he was appointed before the ship was designed, and for five years he has given all his time and thought to the expedition. He is supported by a band of highly trained specialists, who have spared neither time nor travel in mastering the subjects with which they may deal, and each has also received a general training in the subjects of all his colleagues—an admirable precaution. The captain of the 'Gauss,' who belongs to the Merchant Service, has taken a course of training from the Norwegian whalers off Spitsbergen. He will, of course, be absolute master of the ship and crew in all that concerns order and safety, but he will be under the direction of the leader in all that concerns the plan of the voyage and the execution of scientific work. This arrangement is one which has always seemed to me to be desirable, that the captain of a ship on scientific service should occupy a position in relation to the scientific chief similar to that of the captain of a yacht in relation to the owner; but it is subject to the drawback that a naval officer could not well be asked to accept such a divided command.

Whatever our views as to ideal organisation may be, we are all certain that both expeditions will do the utmost that they can to justify the confidence that is placed in them and to bring honour to their flags. We know that the officers and staff of the 'Discovery' belong to a race which, whether trained in the University or in the Navy, has acquired the habit of bringing back splendid results from any quest that is undertaken.

A Definition of Geography.

The bright prospects of Antarctic Exploration must not, however, blind us to the fact that exploration is not geography, nor is the reading or even the writing of text-books, nor is the making of maps, despite the recognition of leading cartographers as 'Geographers to the King.' These are amongst the departments of geography, but the whole is greater than its parts.

The view of the scope and content of Geography which I have arrived at as the result of much work and some little reading during twenty years is substantially that held by most modern geographers. But it is right to point out that the mode of expressing it may not be accepted without amendment by any of the recognised leaders of the science, and for my own part I believe that discussion rather than acceptance is the best fate that can befall any attempt at stating scientific truth.

Put in the fewest words, my opinion is that

Geography is the science which deals with the forms of relief of the Earth's crust, and with the influence which these forms exercise on the distribution of all other phenomena.

This definition looks to the form and composition of the Earth's crust itself, and to the successive coverings, partial and complete, in which the stony globe is wrapped. We sometimes hear of the New Geography, but I think it is more profitable to consider the present position of Geography as the outcome of the thought and labours of an unbroken chain of workers, continuously modified by the growth of knowledge, yet old in aim, old even in the expression of many of the ideas that we are apt to consider the most modern.

Some Historical Landmarks.

Claudius Ptolemæus, about 150 A.D., gathered into his great 'Geography' the whole outcome of the Greek study of the habitable world. He laid stress on the threefold nature of descriptions of the Earth's surface, the general sketch of the great features of the world alone receiving the name of Geography, the more special description of an area he termed Chorography, and the detailed account of a particular place Topography.

Aristotle, who first adduced real proofs of the sphericity of the Earth, had not failed to note the relationships which exist between plants and animals, and the places in which they are found, and he argued that the character of peoples was influenced by the land in which they lived; but Ptolemy cared little for theories, comparisons, or relationships, confining himself rather to the record of actual facts. He made errors, the results of which were more important, as it happened, in advancing knowledge than were the truths which he recorded; for after the troubled mediæval sleep, when even the spherical form of the Earth was blotted out of the knowledge of Christendom, the scientific deductions made by Toscanelli from the false premises of Ptolemy heartened Columbus for his westward voyage to the Indies, on the very outset of which he stumbled all unknowing on the New World. When Magellan succeeded in the enterprise which Columbus had commenced, the fourteen centuries' reign of Ptolemy in geography came to an end; his work was done.

The rapid unveiling of the Earth in the sixteenth and seventeenth centuries cast a glamour over feats of exploration which has not yet been wholly dissipated, and it may not be easy, even now, to obtain wide credence for the fact that the explorer is usually but the collector of raw material for the geographer.

It is of vital interest to trace the re-formation of the theory of geography after its interruption in the Middle Ages. The fragments of the old Greek lore were cemented together by new and plastic thoughts, crudely enough by Apian, Gemma Frisius, and Sebastian Munster in the sixteenth century, but with increasing strength and completeness by Cluverius, Carpenter, and Varenius in the seventeenth.

The First Oxford Geographer.

The names of Cluverius and Varenius are familiar to every historian of geography, but that of Carpenter, I am afraid, is now brought to the notice of many geographical students for the first time. He was not so great as Varenius, but he was the first British geographer to write on theoretical geography as distinguished from mathematical treatises on navigation or the repetition of narratives of travel, and I think that there is evidence to show that his work had an influence on his great Dutch contemporary.

Nathanael Carpenter, Fellow of Exeter College, Oxford, published his book in 1625 under the title—

'Geographie delineated forth in two Bookes. Containing the Sphericall and Topicall parts thereof,' and with the motto from Ecclesiastes on its title-page—

'One generation commeth, and another goeth, but the Earth remayneth for ever.'

The great merits of Carpenter's treatise are his firm grasp of the relation of one part of geography to another, his skilful blending of the solid part of the work of Aristotle and Ptolemy with that of the explorers and investigators of his own generation, and the wholesome common-sense that dominates his reasoning. His definition is comprehensive and precise.

'Geographie is a science which teacheth the description of the whole Earth. The Nature of *Geographie* is well expressed in the name: For *Geographie* resolved according to the *Greeke* Etymologie signifieth as much as a description of the Earth; so that it differs from *Cosmographie*, as a part from the whole. Forasmuch as *Cosmographie* according to the name is a description of the whole world, comprehending under it as well *Geographie* as *Astronomie*. Howbeit, I confesse, that amongst the ancient Writers, *Cosmographie* has been taken for one and the self-same science with *Geographie* as may appeare by sundry treatises meerely Geographicall, yet intituled by the name of *Cosmographie*.'

The differences held by Ptolemy to distinguish geography from chorography Carpenter shows to be merely accidental, not essential, and as to geography he says 'It is properly tearmed a *Science*, because it proposeth to it selfe no other end but knowledge; whereas those faculties are commonly tearmed *Arts*, which are not contented with a bare knowledge or speculation, but are directed to some farther work or action. But here a doubt seems to arise, whether this *Science* be to be esteemed *Physicall* or *Mathematicall*? Wee answer, that in a Science two things are to bee considered: first, the *matter* or object whereabout it is conversant; secondly, the *manner* of handling and explication: For the former no doubt can bee made but that the object in *Geographie* is for the most part *Physicall* consisting of the parts whereof the Spheare is composed; but for the manner of Explication it is not *pure* but *mixt*; as in the former part *Mathematicall*, in the second rather *Historicall*; whence the whole Science may be alike tearmed both *Mathematicall* & *Historicall*; not in respect of the *subject* which we have said to be *Physicall* but in the manner of *Explication*.'

Although somewhat diffuse in expression, the meaning of these statements is clear and sound, and to the British public as new now as it was in the days of King Charles. The book treats of mathematical geography and cartography, of magnetism, climates, the nature of places, of hydrography, including the sea, rivers, lakes and fountains, of mountains, valleys and woods, of islands and continents, and at considerable length of people and the way in which they are influenced by the land in which they live. Whether Dr. Carpenter lectured on geography in Oxford I do not know, but his book must have acquired a certain currency, for a second edition appeared in 1635, and it seems probable that it was known to Varenius.

Varenius and Newton.

Varenius, a young man who died at twenty-eight, produced in Latin a single small volume published in 1650, which is a model of conciseness of expression and logical arrangement well worthy even now of literal translation into English. So highly was it thought of at the time that Sir Isaac Newton brought out an annotated Latin edition at Cambridge in 1672.[1] The opening definition as rendered in the English translation of 1733 (a work spoilt in most places by a parasitic growth of notes and interpolations) runs:—

'Geography is that part of *mixed mathematics* which explains the state of the Earth and of its parts, depending on quantity, viz., its figure, place, magnitude

[1] Dugdale, in the introduction to the English translation published in 1733, states explicitly that Newton produced his version for the benefit of the students attending his lectures 'on the same subject' from the Lucasian chair; but we have been unable to find any more satisfactory evidence that Newton actually lectured on Geography at Cambridge.

and motion with the celestial appearances, &c. By some it is taken in too limited a sense, for a bare description of the several countries; and by others too extensively, who along with such a description would have their political constitution.'

Varenius produced a framework of Physical Geography capable of including new facts of discovery as they arose, and it is no wonder that his work, although but a part, ruled unchallenged as the standard text-book of pure geography for more than a century. He laid stress on the causes and effects of phenomena as well as the mere fact of their occurrence, and he clearly recognised the vast importance upon different distributions of the vertical relief of the land. He did not treat of human relations in geography, but, under protest, gave a scheme for discussing them as a concession to popular demands.

Kant.

As Isaac Newton, the mathematician, had turned his attention to geography at Cambridge in the earlier part of the eighteenth century, so Immanuel Kant, the philosopher, lectured on the same subject at Königsberg in the later part. The fame of Kant as a metaphysician has defrauded him of much of the honour that is his due as a man of science. As Professor Hastie puts it: 'His earlier scientific work, like an inner planet merged in light, was thus almost entirely lost sight of in the blaze of his later philosophical splendour.'

Kant, it will be remembered, considered that the communication of experience from one person to another fell into two categories, the historical and the geographical: that is to say, descriptions in order of time or in order of space. The science of geography he considered to be fundamentally physical, but physical geography formed the introduction and key to all other possible geographies, of which he enumerated five: *mathematical*, concerned with the form, size, and movements of the Earth and its place in the solar system; *moral*, taking account of the customs and characters of mankind according to their physical surroundings; *political*, concerning the divisions of the land into the territories of organised governments; *mercantile*, or, as we now call it, commercial geography; and *theological*, which took account of the distribution of religions. It is not so much the cleavage of geography into five branches, all springing from physical geography like the fingers from a hand, which is worthy of remark, but rather the recognition of the interaction of the conditions of physical geography with all other geographical conditions. The scheme of geography thus acquired a unity and a flexibility which it had not previously attained, but Kant's views have never received wide recognition. If his geographical lectures have been translated no English or French edition has come under my notice, and such currency as they obtained in Germany was checked by the more concrete and brilliant work of Humboldt, and the teleological system elaborated in overwhelming detail by Ritter.

The teleological views of Ritter were substantially those of Paley. The world, he found, fitted its inhabitants so well that it was obviously made for them down to the minutest detail. The theory was one peculiarly acceptable in the early decades of the nineteenth century, and it had the immensely important result of leading men to view the Earth as a great unit with all its parts co-ordinated to one end. It gave a philosophical, we may even say a theological, character to the study of geography.

Kant's views had pointed to such a unity, but from another side, that of evolution. It was not until after Charles Darwin had fully restored the doctrine of evolution to modern thought that it was forced upon thinking men that the fitness of the Earth to its inhabitants might result not from its being made for them, but from their having been shaped by it. It is certain that the influence of the terrestrial environment upon the life of a people has been carried too far by some writers—by Buckle, in his 'History of Civilisation,' for example—but it is no less certain that this influence is a potent one.

The Nature of Geography.

Granted that such influence is exercised, some objectors may urge that geography has nothing to do with the matter, and we are compelled to acknowledge that the meaning and contents of geography are in this country as variously interpreted as the colour of the chameleon in the traveller's tale. Yet my thesis is that it is just this relation between the forms of the solid crust of the Earth and all the other phenomena of the surface that constitutes the very essence of geography.

It is a fact that many branches of the study of the Earth's surface which were included in the cosmography of the sixteenth century, the physiography of Linnæus, the physical geography of Humboldt, and perhaps even the *Erdkunde* of Ritter, have been elaborated by specialists into studies which, for their full comprehension, require the whole attention of the student. Geology, meteorology, oceanography, and anthropology, for example, have been successively specialised out of geography; but it does not follow that these specialisations fully occupy the place of geography, for that place is to co-ordinate and correlate all the special facts concerned so that they may throw light on the plan and the processes of the Earth and its inhabitants. Geography is concerned with the results, not with the processes of the special sciences, and the limits between geography and geology, to take a single instance, are to be drawn, not between any one class of phenomena and another, but between one way and another of marshalling and utilising the same facts. This was clear to Carpenter in 1625, though we have almost forgotten both it and him.

The Principles of Geography.

The principles of geography—the 'pleasant principles,' to use the phrase of old William Cuningham in 1559—on which its claims to status as a science rest are generally agreed upon by modern geographers, though with such variations as arise from differences of standpoint and of mental process. The evolutionary idea is unifying geography as it has unified biology, and the whole complicated subject may be presented as the result of continuous progressive change brought about and guided by the influence of external conditions. These views have been often expressed in recent years, but they do not seem to have been very seriously considered, and no excuse need be offered for presenting them once more, though in an epitome curt to baldness.

The science of geography is of course based on the mathematical properties of a rotating sphere; but if we define geography as the exact and organised knowledge of the distribution of phenomena on the surface of the Earth, we see the force of Kant's classification, which subordinated mathematical to physical geography. The vertical relief of the Earth's crust shows us the grand and fundamental contrast between the oceanic hollow and the continental ridges; and the hydrosphere is so guided by gravitation as to fill the hollow and rise upon the slopes of the ridges to a height depending on its volume, thus introducing the great superficial separation into land and sea. The movements of the water of the ocean are guided in every particular by the relief of the sea-bed and the configuration of the coast lines. Even the distribution of the atmosphere over the Earth's surface is affected by the relief of the crust, the direction and force of the winds being largely dominated by the form of the land over which they blow. The different physical constitution of land, water and air, especially the great difference between the specific heat and conductivity or diathermancy of the three, causes changes in the distribution of the sun's heat, and as a result the simple climatic zones and rhythmic seasons of the mathematical sphere are distorted out of all their primitive simplicity. The whole irregular distribution of rainfall and aridity, of permanent, seasonal and variable winds, of sea-climate and land climate, is the resultant of the guiding action of land forms on the air and water currents, disturbed in this way from their primitive theoretical circulation. So far we see the surface forms of the Earth, themselves largely the result of the action of climatic forces, and constantly undergoing change in a definite direction, controlling the two great systems of fluid circulation

These in turn control the distribution of plants and animals, in conjunction with the direct action of surface relief, the natural regions and climatic belts dictating the distribution of living creatures. A more complicated state of things is found when the combined physical and biological environment is studied in its incidence on the distribution of the human race, the areas of human settlement, and the lines of human communications. The complication arises partly from the fact that each of the successive earlier environments acts both independently and collectively; but the difficulty is in greater degree due to the circumstance that man alone amongst animals is capable of reacting on his environment and deliberately modifying the conditions which control him.

It seems to me that the glory of geography as a science, the fascination of geography as a study, and the value of geography in practical affairs are all due to the recognition of this unifying influence of surface relief in controlling, though in the higher developments rather by suggestion than dictation, the incidence of every mobile distribution on the Earth's surface.

The Classification of Geography.

Following out this idea, we are led to a classification of the field of geography in a natural order, in which every department arises out of the preceding with no absolute line of demarcation, and merges into the succeeding in the same way This classification, it is necessary to note, is not like a series of pigeon-holes, which may be placed in any arbitrary order, but like a chain, in which the succession of the links is essential and unalterable.

Since form and dimension are the first and fundamental concepts in geography, the first and basal division is the *Mathematical.* Mathematical geography leaves the Earth as a spinning ball lighted and warmed according to a rigid succession of diurnal and annual changes. This merges into the domain of *Physical Geography,* which involves the results of contemporary change in the crust and the circulation of the fluid envelopes, with the resulting modifications in the simple and predictable mathematical distributions. This division falls naturally into three parts: Geomorphology, dealing with the forms of the solid crust and the changes they are undergoing at the present time; Oceanography, dealing with the great masses of water in the world; and Climatology, dealing with the effects of solar energy in the air. But all three spheres—lithosphere, hydrosphere, and atmosphere—are so closely inter-related that no one of them can be studied without some preliminary knowledge of the others. This forms the largest and most important part of geography, more varied and intricate than the mathematical, better known and more definite than those involving life.

Bio-geography, the geographical distribution of life, arises directly from physical geography, which dominates it, but it is full of complex questions which involve the biological nature of the organism and the influence of physical environment, in which geographical elements, although predominant, do not act alone. Difficult as some of the problems of the distribution of life are at the present day, the remains of living creatures found fossil in the rocks, and the survivors of archaic forms still lingering in remote islands, supply us with our only instrument of research into the geography of past ages, often making it possible to lay down the areas of land and water in earlier geological periods.

The relation of man to the surface of the Earth detaches itself from the rest of Bio-geography by the number of exceptions to general laws of distribution and by the human power of modifying environment. It has necessarily been formed into a special department, *Anthropo-geography.* In primitive man the control exercised by environment is nearly as complete and simple as in the case of the lower animals; but with every advance in culture fresh complications are introduced. The relation of people to the land they inhabit, the choice of sites for dwellings and towns, the planning and carrying into effect of lines of communication, are all obviously much under the control of land form and climate. When people get settled in a favourable position they usually become attached to it; they acquire, one may say, the colour of the land, in modes of thought as well as in manner of

life. The poems of Ossian and the Crofter Question require for their elucidation a knowledge of the geographical conditions of the Western Highlands, just as the Border ballads and the Border raids were largely conditioned by the geography of the Southern Uplands.

Attachment to the native valley or the native fields leads to the holding of land by clans or tribes and the fusion of tribes into nations, while changes in physical conditions stimulating migration from a deteriorating country may lead to the invasion of settled territories by homeless hordes. Here Anthropo-geography buds off the subdivision of *Political Geography*, which takes account of the artificial boundaries separating or subdividing countries, and of the innumerable artificial restrictions and ameliorations which are superimposed on the natural barriers and channels of intercommunication. Even in political geography only a humble place is held by a statement of boundaries and capitals, to lists of which the great name of Geography has actually been confined by people who ought to have known better.

Anthropo-geography views the world from the standpoint of the race, political geography from the standpoint of the nation; but room has to be found for a yet more restricted outlook, that of the individual, whose view of the world as it profits himself is known as commercial geography. This department deals with natural commodities and their interchange, and perhaps because here rather than in the other departments a successful comprehension of the inter-relation of cause and effect may be, in the language of the schoolroom, 'reduced to pounds, shillings, and pence,' the name of Applied Geography has been proposed. It fitly terminates our survey of the science, for the flickering disturbances of the equilibrium of supply and demand known simultaneously over the whole world, and the slower movements of transport to restore equilibrium, are still far from the power of scientific prevision, and all we can do at present is to point out certain clear lines of least resistance, or greatest advantage, due to the interactions of natural and human causes and effects.

To sum up in a sentence the field and the function of geography in the broad majesty of its completeness, we may say that it is the description of the surface of the solid Earth as it is in itself, as it acts upon the ocean, the air, and the living things which inhabit it, and as it is affected in turn by their actions.

Geography and the State.

Viewed thus I believe that geography will be found to afford an important clue to the solution of every problem affecting the mutual relations of land and people, enlightening the course of history, anticipating the trend of political movements, indicating the direction of sound industrial and commercial development.

It would be possible, unfortunately it would be easy, to enumerate misconceptions of history, blunders in boundary settlements, errors in foreign policy, useless and wasteful wars, mistakes in legislation, failures in commercial enterprise, lost opportunities in every sphere, which are due to the neglect of such a theoretical geography. Surely it is to the laws defining the interaction of Nature and Man that we should turn for guidance in such affairs, rather than to the dull old British doctrine of 'muddling through.' That vaunted process after all means that we are driven by stress of facts to do without intending it or knowing how, and at immense expense, the very things that intelligent study beforehand would have shown to be necessary, feasible and cheap.

All this has been urged again and again, and it has fallen on the ears of those in authority 'like a tale of little meaning though the words are strong.' I admit that all advocates of a rational geography have not escaped the danger of the special pleader—they have promised too much. If a Government official were to say, 'Yes, I confess there was a mistake here, the affair was managed badly, much money and some prestige were lost; it must all be done over again; please tell me how,' I am afraid that the chances are that the answer would be vague, general and unpractical. If the answer to this boldly hypothetical question is ever to be clear and definite, geography must be studied as it has never yet been studied

in this country. It must pass beyond the stage of a recreation for retired officers, colonial officials, and persons of leisure, and become the object of intense whole-hearted and original study by men of no less ability who are willing to devote, not their leisure, but their whole time to the work. The object of geographical research should be nothing less than the demonstration or refutation of what we claim to be the central principle of geography—that the forms of terrestrial relief control all mobile distributions.

A Projected Geographical Description.

In order to focus the question it may be convenient to consider the geography—or chorography, as Ptolemy would have termed it—of the British Islands. No author has ever attempted to give such a description. Camden's 'Britannia' was swamped by archæology; the county histories, which are certainly not deficient in number, were wrecked outward bound on the harbour-bar of genealogy. Sir John Sinclair's old 'New Statistical Account of Scotland' in the intelligent utilisation of very incomplete data was a great but solitary stride in the right direction. Bartholomew's great 'Atlas of Scotland' supplies the cartographical basis for a modern description of the northern kingdom; but the description itself has not been undertaken on an equal scale. The work of producing a complete geographical description of the British Islands would be gigantic, but not hopelessly difficult.

The material has been collected at an enormous expenditure of public money, and is stacked more or less accessibly, much of it well-seasoned, some I fear spoilt by keeping; but there it lies in overwhelming abundance, heaps of building materials, but requiring the labour of the builder before it can become a building.

There is first and chief the Ordnance Survey, one of the grandest pieces of work in mathematical geography that has ever been accomplished. The result is a series of maps almost as perfect as one can expect any human work to be, showing in a variety of scales from $\frac{1}{4}$ of an inch to 25 inches to a mile every feature of the configuration of the land—except the lake-beds.

There is next the hydrographic survey by the Admiralty, giving every detail of the subaqueous configuration in and around our islands—except the lake-beds.

These two great surveys supply the basis for a complete description of the British Islands, and the geological survey, which in a sense is more elaborate than either of the others, completes the fundamental part. The geological map makes it possible to explain many of the forms of the land by referring to the structure of the rocks which compose them. Both the geological and hydrographic surveys are accompanied by memoirs describing the features and discussing the various questions arising from the character of each sheet; but there is nothing of the kind for the maps of the ordnance survey.

The ordnance maps show at the date of their preparation the extent and also the nature of the woodlands and moorlands, and this information is supplemented by the Returns of the Board of Agriculture, which each year contain the statistics of farm crops, waste land, and livestock for every county. These returns are excellently edited from the statistical point of view, but they are not discussed geographically. It is easy to see in any year how much wheat is raised in each county, but it is a slow and laborious process to discover from the Returns what are the chief wheat-growing areas of the country. The county is too large a unit for geographical study, as it usually includes many types of land form and of geological formation. Before the distribution of crops can be understood or compared with the features of the ground they must be broken up into parishes, or even smaller units, and the results placed on maps and generalised. The vast labour of collecting and printing the data is undertaken by Government, and paid for by the people without a murmur, but the geographer is left in ignorance for the want of a comparatively cheap and simple cartographic representation of the facts.

The Inspectors of Mines and the Board of Trade publish statistics of the industry and the commerce of the country, statistically excellent, no doubt, but in

most cases lacking the cartographic expression which makes it possible to take in the general state of the country from year to year. The same is true of the Registrar-General's Returns of births, marriages, and deaths, in themselves an admirable epitome of the health conditions of the country, and of the fluctuations in population, but limited by a narrow specialism to the one purpose.

Finally and chiefly we have the Census Reports. Once in ten years the people are numbered and described by sex, age and occupation. The inhabited houses are numbered, and the smaller dwellings grouped according to size. The figures are most elaborately classified and discussed, so as to bring out the distribution of population, and its change from the previous decade. But to the geographer the Census Reports are like a cornfield to a seeker of bread. The grains must be gathered, prepared, and elaborated before the desired result is obtained. Nowhere is the cartographic method more useful than here. It is a striking contrast to turn to the splendid volumes of the United States Census Reports, many of them statistically inferior to ours, but thickly illustrated with maps, showing at a glance the distribution of every condition which is dealt with, and enabling one to follow decade by decade the progressive development of the country, and to study for each census the relations between the various conditions.

These are only a few of the statistical publications, produced by Government, and embodying year after year a mass of conscientious labour, which, save for a few specialists who extract and utilise what concerns themselves, is annually 'cast as rubbish to the void.'

One small department supported by public money, but under unofficial direction, may be referred to as an example of the successful employment of cartographic methods. This is the Meteorological Council, appointed by the Royal Society, and charged with the collection of meteorological data and the publication of weather reports, forecasts, and storm warnings. The maps published twice daily to show the distribution of atmospheric pressure and temperature are only rough sketches and very much generalised, yet they serve the purpose of presenting the facts in a graphic form, yielding at a glance information which could only be extracted from tables by long and laborious efforts. The pilot charts, published monthly by the same department, showing the average conditions of air and sea over the whole North Atlantic, and the occasional atlases of oceanographical data are valuable geographical material.

The official work of Government is supplemented by the voluntary labours of many societies, in whose Transactions much valuable material is stored, and in not a few cases is well discussed. But even with these supplements gaps remain which must be filled by private enterprise before a complete geographical description can be compiled.

Considering the Ordnance Survey alone it is much to be regretted that circumstances have prevented the extension of the survey to the lake-beds, whatever reason may be assigned for the omission; yet such is the fact. The directors of the Survey have, however, shown themselves ready to encourage private workers by placing the data presented by them upon the maps with due acknowledgment.

The Survey of the Lakes.

It is with profound satisfaction that I now make an announcement—by special favour the first public announcement—of a scheme of geographical research on a national scale by private enterprise. Sir John Murray and Mr. Laurence Pullar have resolved to complete the bathymetrical survey of all the fresh-water lakes of the British Islands. Mr. Laurence Pullar will take an active part in the proposed survey, and has made over to trustees a sum of money sufficient to enable the investigation to be commenced forthwith and to be carried through in a comprehensive and thorough manner. It is intended to make the finished work an appropriate and worthy memorial of Mr. Pullar's son, the late Mr. Fred Pullar, who had entered enthusiastically upon the survey of the lochs of Scotland, and whose heroic death while endeavouring to save life in Airthrey Loch

last February must be present to the memory of many of you. Large sums of money devoted in good faith to scientific purposes do not always bring about the wished-for result; but in this case there is no room for anxiety on that score. Sir John Murray, with whom Mr. Fred Pullar had worked for several years, has generously promised to direct the whole scheme, and to be responsible for carrying it out. All the lakes of the British Islands will be sounded and mapped as a preliminary to the complete limnological investigation which is proposed. The nature of the deposits, the chemical composition of the water and its dissolved gases, the rainfall of the drainage areas, the volumes of the inflowing and outflowing streams, the fluctuations in the level of the surface, the seasonal changes of temperature, and the nature and distribution of aquatic plants and animals will all receive attention. The geological history of the lakes may also be enquired into with reference to such points as the growth of deltas, the erosion of the margins, and, perhaps, the conditions of the old dead lakes that are now level meadows.

Five years at least will be required to make these observations and to incorporate them in memoirs, each of which will be a complete natural history of the lakes of one river basin. The proposed work wants more than money, direction and time. It requires the services of several young and enthusiastic workers—preferably men who have completed their University course and are anxious to devote some time to research. Sir John Murray and Mr. Pullar wish to meet three or four capable young fellows, one preferably a chemist, one a geologist, one a botanist, and one a zoologist. When found they will be offered a salary sufficient to enable them to give their whole time to the work, but not large enough to induce anyone who has not the love of science at heart to take it up. From my experience when working in somewhat similar conditions at the Scottish Marine Station seventeen years ago, I can promise those who will have the good fortune to be selected plenty of hard work for which they will get the fullest credit—and this they will appreciate more keenly when they come to know the world better—and I can promise them also in their association with Sir John Murray a course of scientific and intellectual training such as even the universities do not afford.

Other Desirable Surveys.

The Geological Map requires to be supplemented by additional work on the nature of the superficial soil as it affects agriculture, such as is expressed in the *Cartes agronomiques* of France, going more fully into the chemical nature of the soil than is possible on the Drift Maps of the Survey which so usefully supplement the maps of solid geology. Such experiments as have been made at the College at Reading in collecting analyses of the soils in the neighbourhood might very well be carried out at the agricultural colleges and other centres all over the country.

Of equal value, though, perhaps, more obviously so to the scientific than to the 'practical' man, is the study of the natural vegetation of the country. In a highly cultivated land like ours there are comparatively few places where the native flora remains in possession, but the mapping of the main crops which have supplanted it is nearly as useful. To become satisfactory from this point of view, the statistics of the Board of Agriculture ought to be supplemented by surveys made by trained botanists on the ground. A valuable beginning has been made under the ever-fertile stimulus of Professor Patrick Geddes in the two sheets of a map of the plant-associations of Scotland compiled by the late Robert Smith, whose premature death last year was a loss to science. It would be a splendid thing if this map could be finished as a memorial to the brilliant young botanist in the same way as the survey of the lakes is proposed as a memorial worthy of Fred Pullar, and I am glad to learn that there is some probability of it being carried on.

Of all the other distributions which might be worked out cartographically time fails us to speak; but reference must be made, however briefly, to a few.

Geography of the Air.

With regard to Meteorology, the distribution of temperature and pressure over the British Islands for the year and for the separate months have been worked out by the experienced hand of Dr. Buchan and published both in separate memoirs and in the 'Meteorological Atlas,' edited by Dr. Buchan and Dr. Herbertson. But such observations as the degree of cloud or of sunshine can as yet be treated only in a superficial and generalised way for want of data. Perhaps the most important and certainly the most difficult of all the atmospheric conditions to discuss fully is precipitation. It depends on so many varying conditions, such as the form and exposure of the land, the altitude above sea-level, the direction and force of the wind, the relative frequency of thunderstorms, the distance from the sea, the direction of the average paths of cyclonic storms, &c., that far more numerous and more long-continued observations are required to establish the normal condition of the country than in the case of either temperature or pressure. When we reflect that the whole water-supply of the country depends directly on rainfall, and when we remember that the value of water-power made available by differences of level promises to be greater in the future than it has been in the past, we can see that a study of rainfall in conjunction with configuration may prove as valuable for the localisation of the manufacturing centres of the future as the geological survey was for those of the present.

Thanks to the remarkable foresight and the untiring exertions of the late Mr. Symons, the volunteer rainfall observers of this country have been encouraged to organise their efforts, and by working on a common plan have accumulated within the last forty years a mass of observations unrivalled for number and completeness in any other land. But as yet the difficulties in the way of constructing a map of normal rainfall on an adequate scale have not been overcome, and much experimental work will probably be necessary before it can be accomplished. To this task it is my ambition to devote myself. I may be permitted to state that Scotland is far behind England or Wales in the number of rainfall stations per square mile. Thus there is, roughly, one rain-observing station for every 20 square miles of England, one for every 30 square miles of Wales, but only one for every 67 square miles of Scotland, and one for every 170 square miles of Ireland.

Rainfall observations only tell the amount of available water; the configuration of the stream-beds must be considered in determining water-power. The only country I know where the horse-power of the rivers has been measured and mapped is Finland, but of course individual rivers, such as the Mississippi, Rhine, Seine, and Thames, have been thoroughly studied. Before many decades have passed it will be a necessary element in the surveys of all countries, though at present the available data are few and scattered.

Population Maps.

In considering human geography we come to the most interesting and least occupied field of research. Until Mr. Bosse constructed his beautiful maps of the density of population of Scotland and England we had absolutely no cartographical representation of the true distribution of people over the land. To map population by counties gives a very poor idea of the truth, for in such counties as Yorkshire or Perthshire there are large areas entirely without inhabitants, and small areas where the population is very dense. Mr. Bosse's maps were made on the principle of leaving blank all the land on which there were no dwelling-houses, and so obtaining a close approximation to the true density of population of the inhabited area. For Scotland his map shows at once that it is a function of configuration. It shows the densely peopled lowland plain, the less densely peopled coast-strip surrounding the country, and the least densely peopled valleys running inland into the great uninhabited areas. The population map of England, on the other hand, shows an absolutely startling relation to the geological structure,

which in turn is closely related to the configuration. We are not astonished to see the centres of densest population coinciding with the Coal Measures, but it is both surprising and instructive to see how the density of population runs parallel to the strike of the Secondary and Tertiary rocks of south-eastern England, a band of the lightest population following each outcrop of chalk and limestone, a band of dense population following each belt of sandstone or clay.

Anthropo-geography teems with fascinating subjects of research. The admirable investigations in the West of Ireland on the physical anthropology of the people might well be extended to the whole country outside the great towns, where all evidence of place of origin and original character is speedily lost. Good work has been done in this way by the Ethnographic Survey promoted by a committee of this Association, and a committee of the Royal Scottish Geographical Society has rendered great aid to the Ordnance Survey in the cognate study of the place-names of Scotland.

The distribution of religion, even in the three typical forms of Anglican, Presbyterian, and Roman Catholic—forms so typical as to be, broadly speaking, national—is most imperfectly known. The objection to a religious census is one which is somewhat difficult of comprehension in Scotland, and too polemic for sober discussion in England. But a few of the problems are worth being worked out by individuals. The curious islands of Roman Catholic continuity in Lancashire, the Hebrides and the Highlands can probably be related simply enough to the configuration of the country and the means of communication as influencing free movement of people at critical periods of history. There are many interesting points as to the geographical distribution of surnames, the relation of characteristic literature or poetry to specific areas; things small in themselves, but capable of exercising very far-reaching influence if systematically worked out.

Geographical Synthesis.

Granted that the subsidiary surveys have been made and the results put in a strictly comparable form, the central problem remains—the synthesis of the complete geography of the country. This can perhaps be solved best by comparing the maps of the various distributions in the proper order, and seeing how far they are related to one another. For the general discussion the Ordnance Map on the scale of 1 inch to a mile should be used, and each natural region ought properly to be treated by itself, but as a matter of practical convenience it would probably be found best to select either the artificial boundaries of counties or the still more arbitrary lines bounding sheets of the map. Whatever small area is taken as the unit of description, it should be treated in such a way as to seek for and prove or disprove the existence of any control exercised by the form of the land and its geological character on the outcrops of the rocks, the nature of the soil, the course of the rivers, the temperature and movements of the air, the rainfall, the vegetation and agriculture, the distribution of population, the sites of towns, villages, and isolated dwellings, the roads, railways and harbours, the birth-rate and death-rate, and on the progressive changes in all these conditions which are shown in the discussion of the statistics collected annually or decennially. When such unit areas are worked out individually the results can easily be combined and condensed into a geographical description that will be complete, well balanced, and symmetrical. The work is practicable; it requires only time, money, direction and workers to carry it out; but although a specimen memoir, prepared by the authority of the Royal Geographical Society, met with a certain measure of approval, all attempts failed to obtain funds for making the work complete, and the scheme must await a more educated generation before it can be profitably revived in its entirety. Meanwhile this field for geographical study and research lies at the doors of every university where the subject is or may be recognised, and the labours of professors and students might be profitably directed to the completion of such memoirs for the surrounding district, gradually working further and further afield. The idea is no more new than every other 'thing under the sun.' Such exercises, not so elaborately planned, but the same

in essentials, were ordinary subjects for theses in the universities of Sweden and Finland during the eighteenth century. To come nearer home, the local handbooks prepared for successive meetings of the British Association are frequently very fair examples of the geographical description of a district. The essential qualities are rarer in guide-books, but we must not forget one brilliant exception, the poet Wordsworth's 'Guide to the English Lakes.'

It is pleasant to hear that through the encouragement of Sir John Murray the Scottish Natural History Society is taking up the systematic study of the basin of the Forth, and they will, I feel sure, give a good account of their labours. One point which must be very strongly emphasised is that a geographical treatise is distinguished from a jumble of facts mainly by the order and proportion in which the phenomena are dealt with, and by the relation of cause and effect that is established between them.

As to the utility of complete geographical descriptions, we must of course recognise their greater practical importance in new and developing countries than in old lands like our own. Yet even with us the study of the distribution of natural resources may suggest important changes, involving great redistributions of population.

A Geographical Warning.

Hitherto, except as regards exploration and cartography, the position of geography in this country has never been satisfactory. Times are changing, and even in exploration we are now only one amongst many rivals, often better equipped by education, usually in no way deficient in daring. Although the best work of several of our cartographers in Edinburgh and London need fear no comparison, we cannot conceal the fact that Germany leads the world in map-making. As regards the recognition or even the comprehension of geography by the State, by the universities and by the public, we are equally far behind our neighbours across the North Sea.

It has sometimes been hinted that the study of geography has been deliberately discouraged by politicians or by merchants because too much knowledge on the part of the public might embarrass foreign policy or lead to mercantile competition; but we surely cannot entertain such unworthy suspicions. I am inclined to attribute the neglect of the subject merely to ignorance of its nature due to imperfect education.

Two cases in which the application of geography to political and practical affairs suggests a definite course of action may be mentioned as examples. There is still one important colonial boundary entirely undelimited in a region somewhat difficult of access and still little known, where goldfields will probably be found or reported before long, and where a very serious international question may suddenly arise in a part of the world absolutely unsuspected by most people, even amongst those who interest themselves in general politics and in colonial affairs. It would cost a comparative trifle to survey the region in question, and to lay down that boundary line before the goldfields are touched, so that no international trouble could ever arise. What it may cost to postpone the matter until claims have been pegged out on debatable land, the British Guiana and Venezuela arbitration, the Alaska difficulty, and South Africa are there to tell us. It would be interesting to calculate, now that the cost of a week of fighting is known, the saving in pennies on the income tax that would have accrued from a survey of South Africa if that had been carried out as an imperial duty when Cape Colony was settled. I do not for a moment suggest that a survey would have prevented the war; but it is not unreasonable to believe that it would have shortened it by some months. In this connection it is satisfactory to know that a valuable report has been drawn up by a Committee of the British Association, presided over by Sir Thomas Holdich, embodying a scheme for the systematic survey of British protectorates.

The second example comes nearer home. The utilisation of wind- and water-power must increase in importance as mineral fuel diminishes in amount or increases in price. Wind- and water-power will never fail as long as the sun shines

and the land remains higher than the sea; but what may fail unless timely precautions are taken is the power of utilising them for the benefit of the community at large. Are the existing laws as to water-rights, and the absence of laws as to the utilisation of wind desirable and satisfactory? The usual answer to such questions is, 'Why trouble about that just now? These matters are not urgent, other things are.' That argument is answerable for many disasters. The inevitable is in many if not in most cases simply another name for the unforeseen. It is inevitable that the country will be impoverished if the utilisation of wind- and water-power and the transport of that power by electricity are not wisely safeguarded and provided for; but when a survey of our resources, the circulation of the air over our islands, and the effects produced by the interposition of the mountains, plateaus, and valleys upon it, plainly points to the possibility of such a trouble, it only becomes inevitable as a result of culpable negligence.

These two examples, which will not strike anyone whose mind is wholly occupied in paying the penalties of old neglect, illustrate my contention that a complete geographical description based on full investigation is of the highest and most urgent importance, not for this country only, but for the Empire, and for every country in the world.

Nor is it the land alone which claims attention. It is of the utmost importance to investigate and evaluate the resources of the surrounding seas. The recent International Conference for the exploration of the sea held at Christiania formulated a scheme of research which has been taken up enthusiastically by Belgium, Holland, Germany, Denmark, Russia, Sweden and Norway. Its object is to place the fisheries of Northern Europe on a scientific basis, and to make for that purpose a comprehensive survey of the sea, which will prove of high value to meteorology, and through it to agriculture as well. The recent work by Mr. H. N. Dickson on the circulation of the surface waters of the North Atlantic in conjunction with similar work by Professor Pettersson in Sweden shows how hopeful such researches are from the purely scientific standpoint, and their practical importance is no less. It remains with our Government to show that this country is not indifferent to an opportunity, such as has never presented itself before, of placing one of our great national industries on a basis of scientific knowledge. This is in my belief one of the cases in which the expenditure of thousands now will mean the saving of millions a few years hence.

It is magnificent to send out polar expeditions; they speak volumes for the greatness of the human mind that can give itself to the advancement of knowledge for the sake of knowledge, knowing that it will bring no material gain; and I trust that such a spirit will continue to manifest itself until no spot on Earth, no land however cold or hot, no depth of sea, no farthest limit of the atmosphere remains unsearched and its lesson unlearnt. But I insist that the full study of our own country is on a totally different footing. Magnificent it may be, too, but sternly practical, since it is absolutely essential for our future well-being, and even for the continuance of the nation as a Power amongst the states of the world. Still, there is every probability that such work will be neglected until the events which it should avert are upon us, and then it will be too late to make provisions which now could be done cheaply, easily, and effectively.

A Proposed Remedy.

The few attempts which have been made in this country to promote the study of geography or to diminish the discouragements to geographical research have had but slight success. Much has been done to improve geographical teaching by the Royal Geographical Society, the Royal Scottish Geographical Society, the Geographical Association, this Section of the British Association, and other bodies; but that is not my theme. I refer to the little that has been done towards the elaboration of a geographical theory and the elucidation of geographical processes. Amongst the not inconsiderable number of teachers of geography in the Universities and colleges of Great Britain there is not one man who receives a salary on which he can live in decent comfort so as to

devote all his time, or a substantial part of it, to geographical research; and the same is true of every official of all the geographical societies. Not one is paid a salary sufficient to enable him to devote the time not occupied by mechanical routine to any other purpose than supplementing his income by outside work—writing text-books, correcting examination papers, perhaps even practising journalism. If by an effort and the sacrifice of some of the comforts considered necessary by most people of the professional classes he devotes a few odd hours now and then to some original research, he finds very few to consider it seriously; some friendly expressions of opinion possibly, but scarcely a reader; and it counts for nothing, save, perhaps, in enhancing the reputation of his country in other lands where scientific work, no matter in what department, is valued in a due degree. All this must be changed before much progress can be made. No doubt a giant of genius would ignore all obstacles and pursue his work regardless of recognition; but such giants are not to be looked for many times in a century. It should be made possible for a man of fair abilities to receive as much opportunity, encouragement, recognition and reward for good work in geography as for good work, let us say, in chemistry or electricity. That is all that can reasonably be asked, and that is what is freely accorded in other countries where the status of the man of science is higher than it is with us. It is here that help may be hoped for from the Scottish Universities in the strength of their new endowments. If a Chair of Geography were instituted with the purpose of promoting research first and teaching afterwards, properly equipped with books, maps, and apparatus, and held on the understanding that no outside work was to be undertaken, something might yet be done to restore our country to the position it held a century and a half ago, when a text-book of geography was published without a thought of sarcasm, containing a frontispiece representing 'Britannia instructing Europe, Asia, Africa, and America in the Science of Geography.'

The following Papers and Report were read:—

1. *Martin Behaim of Nürnberg*, 1459–1507. *By* E. G. Ravenstein.

Martin Behaim of Nürnberg fills a place of some prominence in the history of geography on three grounds: firstly, the famous historian João de Barros, writing in 1539, tells us that he was a pupil of Regiomontanus, and was appointed jointly with Master Rodrigues and Master Josepo, a member of a committee who devised a method of 'navigating by the sun,' which had become necessary since the Portuguese had crossed the equator, and left behind them the pole star to determine their latitude; secondly, Behaim claims to have commanded a vessel in Cão's memorable second expedition: and thirdly, during a visit to Nürnberg, in 1490–1493, he superintended the manufacture of a terrestrial globe, which survives to this day, and is the most ancient geographical monument of that kind in existence. As to the first point we may well doubt whether Behaim was a pupil of the great Franconian astronomer, for Regiomontanus left Nürnberg in July 1575, and Behaim was intended for a commercial and not for a scientific career. We know, on the other hand, that José Visinho, the Josepo of de Barros and a pupil of the astronomer Zacuto of Guimarães, actually did translate the 'Almanach Perpetuum' of his master (it was printed at Leiria in 1496), and in 1484 undertook a voyage to the Guinea coast for the especial purpose of determining the latitudes with the aid of the astrolabe and the tables of the declination of the sun, furnished by Zacuto. Behaim may have accompained José on this voyage. It has been suggested that he introduced into the Portuguese navy an 'improved' astrolabe, the cross-staff or the 'Ephemerides' of Regiomontanus; but these are mere idle conjectures.

Nor can we admit that Behaim was a member of Cão's second expedition, which left Lisbon towards the close of 1485 and was back before August 1486. Behaim's own account we gather from the legends on his globe and information evidently communicated by him to Hartmann Schedel, the compiler of the well-

known 'Liber Chronicorum.' He claims to have left Portugal in 1484 in command of one vessel, the other being commanded by Cão; to have set up a Padrão on Monte Négro on January 18, 1485; and to have turned homeward after a voyage of 2,300 leagues. As measured on his globe these 2,300 leagues would have carried him, far beyond the Cape of Good Hope, to a 'Prom. S. Bartholomeo viego,' whilst Cão turned back on a Cabo Negro (now known as Cape Cross) in 15° 14′ S. If Behaim was knighted on Friday, February 18, 1485 (day of the week, date, and year are in agreement), he cannot have set up a pillar on January 18, 1485. But even supposing all these inconsistent dates of his to be due to lapses of memory, we should still hesitate to admit his having been a companion of that famous explorer, still less would a man who wrote in 1493 that 'the polar star not being visible to the south of the equator and the magnet refusing to act the navigators are constrained to make their course with the aid of the astrolabe' have been placed in command of a Portuguese vessel. Behaim has nothing to say about the powerful Manicongo 'discovered' by Cão, but seems to know everything about King Furfur's Land (Benin), where the 'Portugal pepper' was discovered in 1485; about the mysterious 'Ogane,' supposed to be Prester John; and about the great mortality in the Gulf of Guinea owing to the heat. But these are experiences of the expedition of João Affonso d'Aveiro, who left Portugal in 1485 and returned in 1486 in time for Behaim to enter into a scheme for the discovery of the 'island of the seven cities,' as supposed by Ernesto do Canto. We therefore think it quite possible that Behaim took part in d'Aveiro's expedition, but reject unhesitatingly his claim to have commanded a vessel in that of Cão.

As to the globe still to be seen at Nürnberg there is no doubt that it was produced under his direction, and I propose shortly to publish a full description of it, together with a trustworthy facsimile.

2. *Report on the Climatology of Tropical Africa.*—See Reports, p. 383.

3. *Morphological Map of Europe. By* Dr. A. J. Herbertson.

4. *Geographical Conditions affecting British Trade. By* Geo. G. Chisholm, *M.A., B.Sc.*[1]

Fluctuations in British trade are often discussed as if they depended solely on such matters as tariffs and bounties, the ignorance and negligence or knowledge and enterprise of merchants, the behaviour of masters and men among the industrial classes, railway rates, and so forth. It may therefore be worth while to call attention to some obvious facts showing that geographical conditions are important factors to be taken into account in considering such changes.

The history of Glasgow furnishes a very interesting illustration of this truth. Throughout the separate history of Scotland, Glasgow was a town of quite minor importance. Not till trans-Atlantic trade developed did it rise to the position of an important commercial and industrial city. In considering this rise it is important to note that, in relation to such trade, the physical configuration of Scotland gives to Glasgow, as its hinderland, not merely the small valley of the Clyde, but all the originally richer eastern lowlands of Scotland from the Grampians to the Tweed.

In discussing the subject of the Paper with reference to the United Kingdom as a whole, it will be convenient to distinguish between commercial and industrial advantages or disadvantages, even although these act and react on one another.

Commercially, this country has a situation presenting unparalleled advantages in relation to those parts of the world most conveniently reached from the

[1] Published in full in the *Geographical Journal*, October 1901.

seaboard, but no others. The importance of these advantages is well illustrated by the great magnitude and the remarkable constancy in the relative value of the British entrepôt trade, and also by the rapid development and continued pre-eminence of our chief textile industry, that of cotton.

Such being the essential nature of British commercial advantages, all improvements in connection with shipping, the change from wood to iron and steel as ship-building materials, the change from sails to steam as a means of propulsion, the improvement of marine engines, the enlargement of ships, the improvement and enlargement of harbours, the improvement of the means of communication between the seaboard and the interior in all parts of the world, have tended in the aggregate more to the advantage of this country than any other.

On the other hand, all improvements in the means of communication between inland centres of production and inland markets have tended to diminish the relative value of the commercial position of this country. This consideration is illustrated by reference to some facts in the history of the trade of Germany with surrounding countries, and that of the United States with Mexico and Canada.

The industrial advantages of the United Kingdom depend on the great abundance of coal and iron ore in convenient situations. It is obvious, however, that the development of similar resources elsewhere must reduce the relative value of these advantages. With reference to this point the position of two rival countries is of peculiar interest for different reasons. Germany is so favoured, both in its coal and iron fields, that one is led to ask why that country was so long in becoming a rival in industry of the United Kingdom. The United States is even more favoured, and in the case of that country the interesting point to note is how the advance of time is tending to increase its industrial advantages relatively to those of our own country.

Another circumstance tending to lower the industrial advantages of this country relatively to those of others is the development of water-power. Formerly the use of this power was restricted by natural obstacles, but now these obstacles are, to a large extent, removed by the employment of electricity as a means of transmitting that power. All this must obviously tend more to the advantage of such countries as Switzerland, Norway, and Italy in Europe, and Canada and the United States in America, than to that of this country. Under this head the case of Italy is of peculiar interest. Water-power is there getting very largely applied through electricity. Now, it is to be borne in mind that Italy has an extremely advantageous commercial situation. That was shown by the whole history of commerce in the middle ages. The opening of the Suez Canal has restored, to some extent, this advantage, which, however, has not yet been fully or even largely turned to account. But in commerce the great law is that to him that hath shall be given. If, then, Italy, through her water-power or in other ways, is able to develop very greatly a trade based on her own resources, all the more likely will she be to add to that trade a great transit and entrepôt trade such as she once possessed.

5. *The Influence of Geographical Environment on Political Evolution. By* ALLEYNE IRELAND.

The influence of geographical environment on political evolution in the tropics and sub-tropics is a subject which must assume for us an increasing practical interest as time passes. In order to emphasise this point it is only necessary to observe that, taking the tropics and sub-tropics to mean the heat-belt lying between 30° N. and 30° S., the sea-borne trade of these regions is increasing at a much greater rate than is the sea-borne trade of the temperate lands.

We know that commerce to-day demands for its best development certain conditions of government which must in the main conform to the usages of what we call Western Civilisation. Thus the construction of the Suez Canal involved the Europeanising of the Egyptian Government, as the Panama or Nicaragua Canal of the future will involve the establishment, under one authority or another,

of a type of government in Central America very different from that which now exists.

It would be easy to multiply indefinitely examples intended to prove the interdependence of commerce and political administration. The history of British rule in India might well be founded on that central idea; and from the earliest times European relations with China have been moulded by the failure of the Chinese political system to meet the necessities of European commerce.

A brief survey of the history of tropical and sub-tropical countries during the past four centuries confronts us with the fact that in three countries only—Mexico, Peru, and India—did the first European travellers find native Governments possessing any serious elements of stability, and that in each case the government was in the form of a military despotism. Broadly speaking, we may say that whatever degree of organised government exists to day in Central and South America, in the West Indies, in the whole of Africa, in Further India, and in the Malay Archipelago is due to the intrusion of one or another of the European Powers. These countries may be divided into two classes—one comprising those in which the administration is of direct European origin, the other including those in which popular representation effectively throws the control of affairs into the hands of the local inhabitants. If we accept India as representing the former class, and the Central American Republics as representing the latter, we cannot fail to be impressed by the fact that, although European influence in Central America antedates British influence in India by a full century, the argument on the facts is strongly against the applicability of representative institutions to tropical countries.

Briefly the question resolves itself into one of climatic discipline. In Europe the extreme range of temperature demands variety of clothing, and to this necessity we may attribute the growth of industry in early times. A winter season, during which food cannot be obtained directly from the soil, involved an excess of labour above the daily need during the season of crops, and from this we adduce the development of thrift and foresight. To these two factors, and to their innumerable and far-reaching corollaries, must be attributed the general character of European civilisation. In the development of the tropical man neither of these great agencies has been at work, nor, except in a few special instances, can it be foreseen that they will come into operation.

It is not asserted that the natives of the tropics are necessarily deficient in the intellectual faculties. To propound such a theory, in view of the constant and deserved success of East Indians and Negroes in our Universities and at the Bar, would merely betray colour prejudice. But when we observe the tropical man as a legislator or as a responsible administrator we find him, with very few exceptions, to be utterly unsuited to his task. I think that the available facts justify the theory that the climatic conditions of the tropics have set an insuperable barrier to the advancement of tropical peoples in the direction of popular government. It seems to me that a great deal of futile experimenting would be saved if we accepted the principle that in the heat-belt of the world administrative affairs must rest in the hands of specially trained Europeans, guided by the advice of a nominated council consisting of representatives of each class of the community.

It is not because we would oppress the native, but because we would save him from oppression and from the evil effects of rash and ill-considered legislation, that we would take the administration of his country out of his hands.

6. *Itineraries in Portuguese Congo.* *By* Rev. Thomas Lewis.

The ancient kingdom of Kongo discovered in the fifteenth century is so little known at the beginning of the twentieth. In past generations the Portuguese were more interested in their island plantations, and used their territories on the mainland to supply them with slaves. The Government of to-day shows signs of activity in opening up the country, and have established three military and fiscal stations inland, the latest on the Kwangu River.

The traveller finds the river banks from the coast to Moqui sparsely populated. Moqui itself is very unhealthy, but is indispensable as the principal port and depôt for goods into the interior. From here he starts on his inland journey, and travels for six days through dreary and monotonous country to S. Salvador, the ancient capital of Kongo.

Here there are ruins of ancient churches, and the main arch of the cathedral is in a good state of preservation, the only monument of a great and glorious past. There is a Portuguese Resident, two trading firms, and two missions.

Three years ago the writer of this paper was requested to make a prospecting journey into Zombo, and after traversing the country in several directions established a mission station at Kibokolo, in the heart of Zombo.

Travelling east from S. Salvador he ascended the plateau at Bangu, where the Mbrizi River falls into the valley, the Arthington Falls. The journey proceeded eastward, and the source of the Mbrizi was noted. The Kwilu River also rises on this plateau. Two days' journey takes him to the Lufunde Valley, the high, precipitous rocks and waterfalls on both sides of which are very picturesque. The river Lufunde flows into the Mbrizi to the south-west.

Climbing the hill on the eastern side the traveller is again on the plateau, and Kibokolo is a populous district on the highland, 30,250 feet above the sea.

The climate is much better on the plateau than in the swampy lowlands, and the temperature is much lower, with a good annual fall of rain.

The soil is sandy and the country naturally well drained, the most noticeable feature being the abundance of water in sparkling and crystal streams and the absence of swamps. Hence these highlands of Zombo are much healthier for Europeans, and malarial fever is not prevalent.

The flora of the country affords a splendid field for botanists. Many parts of Portuguese Congo are sparsely populated, but Zombo is an exception, being very thickly populated.

When slavery and native wars and superstitions are done away with the natives of Africa will rapidly increase in number, and the question of the native races will be the most difficult of African problems.

The development of the country must be by the uplifting of the natives. New needs and new tastes must be cultivated, so that the natives may be impelled to work for their living.

Here Christian missions do great good in teaching the people and providing them with vernacular literature, so that they are no longer satisfied with savage life. Young men are trained as carpenters, stonemasons, and blacksmiths, and they employ themselves in useful work. Thus the natives take their position as responsible beings in the progress and development of their country.

FRIDAY, SEPTEMBER 13.

The following Papers were read :—

1. *The Effects of Vegetation in the Valley and Plains of the Clyde.* *By* G. F. SCOTT-ELLIOT, *M.A., B.Sc., F.L.S., F.R.G.S.*

General characters of the valley in (1) the subalpine, (2) heather and peat, (3) sheep pasture, and (4) arable districts; (5) the Falls of Clyde or canyon, (6) the valley below the falls, and (7) the flat alluvial plains about Renfrew.

Erosion.—The effect of erosion on peat, bare arable land, and permanent pasture is contrasted with a view to showing that the water retained in peaty soil, the transpiration amounts of living plants, as well as the vegetable matter produced, must so alter the character and amount of the erosion that no trustworthy estimate can be formed if these factors are disregarded.

Slopes or sides of the valley.—The successive stages in the formation of the slope are traced in several instances, taken from the Falls of Clyde and the

tributaries Nethan and Harpersgill, &c. It is shown that a perfect series of transitions can be found from the vertical cliff or scaur left by the river to the continuous steep slope, which is characteristic of the valley-sides throughout this neighbourhood.

The vegetation is shown to control this slope formation throughout. The vegetation covering the space at the base of the cliff forms very rapidly. The annual formation of wood and other tissues is shown to be very great in this sheltered and moist situation (as compared by measurements with the growth of the same plants in more exposed positions). Any falls from above, such as stones or rock, earth and vegetable matter washed or blown down, accumulate at the base of the precipice or scaur, and are at once covered over by the vegetation. Thus a steep sloping surface is formed which gradually extends up the side of the cliff until eventually the characteristic V-shape of the ravines is produced.

Measurements showing the average slopes in at least four separate ravines were given.

The undermining of the rock below the fringe of vegetation is shown in some cases to result in a slope which eventually unites with the accumulation from below to form the characteristic angle of inclination.

The character of the vegetation of course alters greatly the tenacity of the covering formed by it. Thus trees form an exceedingly strong network of roots, as is shown by the example at Kenmuir, where landslips affecting the whole face of the slope have appeared through the original trees having been destroyed.

An attempt was made to give measurements of the average tenacity of the vegetation crust in a few cases, provided the practical difficulties can be overcome in time.

Holmlands or flats or valley floors.—Character, value, and constitution of the holms at different points of the Clyde contrasted, and their differences shown to depend on the mixtures of soils and proportions of organic material. The formation of these flat lands is shown to depend chiefly on the work of certain marsh plants, of which *Scirpus lacustris*, *Phragmites*, *Vaucheria*, *Poa fluitans*, and various sedges are the most important. The difficulty of tracing their action arises from the extent to which draining has been carried on, but observations are given illustrating the species mentioned, and showing that the amount produced in a single year is by no means an inconsiderable quantity.

Shingle beds.—The shingle beds and the manner in which they are covered by vegetation is also discussed shortly.

An attempt is made to show on the map the approximate boundary of what was at one time river and estuarine marshes. The difficulty of deciding upon the exact boundary line is shown to depend upon the amount of boulder clay and drift which closely resembles the ordinary alluvium. If time is left, an attempt will be made to compare the alluvial formations of other countries with those of the Clyde.

2. *The Scottish Natural History Society's Scheme for the Investigation of the Forth Valley.* *By* MARION NEWBIGIN, *D.Sc.*

The paper gives an account of a scheme which has been undertaken by the Scottish Natural History Society at the suggestion of Sir John Murray. It is proposed, first, to arrange, in a readily available form, references to papers already published on the natural history of the Forth Valley, including its botany, zoology, and geology; secondly, the Society proposes to utilise its various sections and the labours of its individual members in the acquisition of a mass of detail in regard to the existing organic conditions in the valley of the Forth, with the primary object of providing a basis of fact upon which conclusions may be later established, although the opportunities of the work as a means of training observers will not be lost sight of. It is hoped that the work may be carried out in such a way that the conditions of existence of the most important organisms within the area may be readily ascertained by reference to the Society's records.

3. *Methods and Objects of a Botanical Survey of Scotland.* *By* W. G. Smith, *B.Sc., Ph.D., Leeds.*

The botanical survey now under consideration was initiated by Robert Smith, of Dundee, and was drawn up in co-operation with a survey of France on similar lines, the project of Professor Ch. Hahault, of Montpellier. According to this method the vegetation of any area is regarded as consisting of a collection of plant-associations the distribution and extent of which are indicated on standard maps by distinctive colours. Each association of plants is adapted to certain conditions of food-supply, heat, light, moisture, &c., and one of the objects of the survey is to obtain fuller information on these life-conditions of plants.

Each plant-association consists of a variable number of species, which may be arranged thus:

(*a*) One or more dominant social (gregarious) species: these are used to name the association, *e.g.*, oak, beech, pine, heather, &c.
(*b*) Secondary social species struggling for dominance.
(*c*) Dependent species protected by the dominant forms or more or less dependent on them for food, &c.

A feature of the survey is the collection of field-notes and lists of species in order to amplify our knowledge of plant-associations and species included in each.

In Scotland the following have been found to be the most suitable associations for recording, and they are equally applicable to a botanical survey in progress in various parts of England:—

I. Maritime and littoral group of associations.

II. Agrarian group.

(*a*) Cultivation: (1) with rotations including wheat—upper limits, 500 to 600 feet; (2) without wheat—up to limits of cultivation, 1,000 to 1,250 feet.
(*b*) Woods of deciduous trees: (1) mixed deciduous woods with beech, oak, &c.—upper limits, 700 to 1,000 feet; (2) oak woods without beech—upper limits, 1,000 feet.

III. Sub-alpine group (1,000 to 2,000 feet).

(*a*) Woods: (1) Scots pine or mixed conifers—upper limits, 1,250 to 1,800 feet; (2) larch woods—upper limits, 1,300 to 1,800 feet; (3) birch woods—upper limits, 1,500 to 2,000 feet.
(*b*) Hill pasture and moorland: (1) grass hill pasture associations; (2) heather associations; (3) cotton-grass and heather associations on peat-bog.

IV. Alpine group (2,000 to 4,000 feet).

(1) Heather associations, up to 3,100 feet.
(2) Bilberry (*Vaccinium myrtillus*) association, up to 3,600 feet.
(3) Alpine pasture associations.
(4) Alpine plateau with mosses, lichens, &c.
(5) Alpine crags.

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4. *Notes on Argentine Anthropo-geography.* *By* F. P. Moreno, *Director of the La Plata Museum.*

The paper gives an account of the distribution of the extinct and existing human races in the Argentine Republic.

There are in Argentina the remains of men who lived before the continent had acquired its present relief and contour. Afterwards these men, developing, commenced their migrations, while another race appeared in the regions of the West at the end of the Glacial epoch, and the ancient people were pushed to the

South, where to-day we meet their descendants; and amongst them we note an extraordinary variety of types observed in no other country in the world. Man lived in caves with extinct mammals as man lived in European caves of the Pleistocene period, and other people migrated from the northern extremity of the American continent. We find Polynesian anthropological elements mixed with the Patagonian, Polynesian culture among Calchaqui and old Peruvian culture. Advancing in time, we find a complicated civilisation which it is impossible to ally with any known type, yet presenting an astonishing similarity in some respects with that of people who lived in the same latitude in the northern hemisphere and in lands of similar physical conditions. There is a remarkable analogy between the petrographs extending from Arizona to Patagonia, on both sides of the Andes, and between their industrial arts and myths. In intermediate countries there are identical analogies with races of the South and of the East. In Bolivia the ruins of Tiahuanaco and other similar ruins have no antecedents; the people to which they are referred, the one that used the macrocephalic deformation, has its representatives from Vancouver to Patagonia; in the old Peruvian pottery the human types are not all those of the natives of to-day, but those of Patagonia, Tierra del Fuego, and Chile; in this pottery Mexican types appear represented as prisoners; several small artistic terra-cottas, so common in the old Mexican towns, have been discovered in the pampas of Buenos Aires; while other Mexican objects are the same as some of Calchaqui. Calchaqui remains extended from the Atlantic to the Pacific, and from Patagonia to Peru an inter-Andean trade has existed in remote epochs showing the enterprise of the peoples which maintained such relations across so great a barrier. When we remember all these facts, we cannot but believe that man in South America has had a very long existence, and that intercontinental, and even interoceanic, communications have been maintained from the prehistoric times until the day when the Spanish conquistadors continued the work of the wild tribes in destroying the older civilisation.

But who are the Onas, the Tehuelches, the Gennakens, the Araucanians, the Misiones, and Chaco tribes, the Calchaquis? It is impossible to answer these questions at present. The importance of these investigations has been indicated in the hope that it may conduce to the solution of these problems, but the author thinks that we are already in presence of the elements which formed the old and lost civilisation, the ruins of which are spread over the whole continent of South America. The anthropologist treating of North America only, and ignoring what can be seen in South America, supposes that the latter continent was peopled by the races of the former, and that the ancestors of the Pueblos were also the founders of the old civilisations of Peru and Bolivia; but probably the South American origins are the older, and there is ample evidence in support of this contention. Palæontology has demonstrated that the Pampean mammals migrated from the South to Mexico and the United States, and it is not impossible that men may have taken the northward route. It is true that the Mastodon is both a European and North American mammal, but it is not to be forgotten that its remains are also abundant in South America, in beds of the same age as, or older than, those of North America and Europe.

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5. *Some Explorations of Andean Lakes.* *By* HESKETH PRICHARD.

Itinerary of expedition—The Pampas—Difficulties of transport—Arrival at Colohuapi—The Tehuelche Indians—Their appearance and method of life—Lago Buenos Aires—Santa Cruz—Following Darwin's route—Arrival at Lago Argentino—First down-stream navigation of the Rio Leona—Exploration of Lago Argentino—The Forests—Discovery of a new lake—Homeward.

6. *M. Elisée Reclus' Map on Natural Curvature.* *By* M. RECLUS-GUYON

SATURDAY, SEPTEMBER 14.

The Section did not meet.

MONDAY, SEPTEMBER 16.

The following Papers and Reports were read:—

1. *The Belgian Scientific Expedition of Ka-Tanga.*[1] *By* Captain LEMAIRE.

The duty of a scientific exploring expedition is to study in all its aspects the object which has been assigned to it, and not to concern itself with affairs.

The scientific apparatus and equipment of the expedition were enumerated.

The European staff of the expedition; loss of two of their number who were drowned in Tanganyika; their replacement by others.

Work of the Expedition.

Cartography.—6,600 kilometres of itinerary mapped on a large scale; map of 1 : 1,000,000 in four colours, containing 195 stations determined by astronomical observation.

Terrestrial Magnetism.—117 stations determined by the three magnetic components.

Altimetry.—Remarks upon the establishment of a single table for the determination of altitudes in equatorial Africa by a single reading of the barometer and the thermometer, without the knowledge of these data for the same moment at a point of comparison. Altitude of Tanganyika; the greatest altitudes noted.

Meteorology.—Four stations for observation were at work from August 1898 to August 1900, furnishing data relating to temperature, atmospheric pressure, moisture, evaporation, duration of insolation, radiation from the earth, atmospheric precipitations, the nature and direction of clouds and winds, the transparency of the air, &c. Certain remarkable phenomena.

Geology.—The geologist and the prospector of our expedition have drawn up detailed reports, accompanied by maps and geological sections. Forty cases of mineralogical specimens were collected.

Fauna and Flora.—An *herbarium* was collected: 100 coloured plates have been prepared; ten cases of specimens were brought back. A rapid glance over the economic fauna and flora of the country traversed.

Ethnography.—Anthropometric determinations; ten cases of collections.

Photography and Painting.—350 photographs; 290 canvasses, water colours, and sketches.

Occupation of the Country by Europeans.—Description of the plateaux of high altitude, 1,790 to 1,900 metres; food-products: European potatoes, wheat, European vegetables, fruits, rice, &c.; domestic animals, both large and small, uninjured by the *tsé-tsé*; the White Fathers of Tanganyika and their admirable work; the steamers on Tanganyika and Moéro; our meeting with Major Gibbons; Anglo-Belgian relations.

2. *Report on Terrestrial Surface Waves.*—See Reports, p. 398.

3. *The Mean Temperature of the Atmosphere and the Causes of Glacial Periods.* *By* H. N. DICKSON, *B.Sc.*

If we suppose that secular variations of climate in the past have been due to changes in the mean temperature of the atmosphere, it is most probable that such

[1] Published in the *Scottish Geographical Magazine*, October 1901.

changes have been accompanied by large relative alterations in the gradient of temperature between the equator and the poles. But this difference of temperature is the primary cause of the whole planetary circulation of the atmosphere, the form and intensity of which must have varied with it, both absolutely and relatively to the modifications produced at the earth's surface by the distribution of land and sea. The general conditions lead to the conclusion that a lowering of mean temperature would be accompanied by an increase of the equator-poleward gradient, and a rise by a diminution of it. Ferrel's theory of atmospheric circulation would then suggest that in the former case the planetary circulation would become more active, the tropical high pressure belts would be displaced to lower latitudes, and the modifying influence of great continental areas would be relatively diminished; while in the latter case the circulation would be less energetic, the tropical belts would be farther from the equator, and the contrast between oceanic and continental climates would be more sharply defined.

The probable effects of such changes on the distribution of precipitation, and especially on the position and direction of the great cyclone tracks, are examined, and it is suggested that the greater proportion of rainfall received with easterly winds on the polar sides of cyclones, in lower latitudes than at present, may explain some peculiar features of glacial phenomena. In any case, the aspects of the problem to which attention is drawn deserve fuller recognition than they have received; they indicate that the variations of temperature required to account for climatic changes are of smaller range than has been supposed, and they may, by the exclusion of some surviving theories, assist in determining the true cause.

4. *Report on a Survey of British Protectorates.*—See Reports, p. 396.

5. *Northern Ontario: Its Geography and Resources. By* ROBERT BELL, *M.D., D.Sc., LL.D., F.R.S., Director of the Geological Survey of Canada.*

Northern Ontario, now also called New Ontario, comprises more than half of the whole province, or all that portion lying north-west of the line of Lake Nipissing and the French River. It has a length of fully 800 miles from Mattawa, on the Ottawa, to the eastern line of Manitoba, near the junction of the Winnipeg and English Rivers, and a breadth of 400 miles from the outlet of Lake Superior to its most northern part, which is at the mouth of the Albany River on James Bay. The eastern boundary, which follows the Ottawa River and the meridian line from Lake Temiscaming, on that stream to James Bay, is also nearly 400 miles in length; but the western half of the region has an average breadth of only 200 miles. Taking the eastern boundary as a base, Northern Ontario is roughly triangular in form, the apex being at the western extremity. The southern boundary is formed by Lakes Huron and Superior and the northern line of the State of Minnesota, while the northern boundary is defined by the English and Albany Rivers and part of the shore of James Bay. The last-named circumstance gives Ontario a claim to be considered a maritime province, with a seaport at Moose Factory, and possibly others at Fort Albany and Hannah Bay. The total area of Northern Ontario is estimated at 72,000,000 acres, or about one and one-third times that of Southern Ontario. Its position lies between lat. 46° N. and lat. 52° N., and the climate is about normal for those degrees of latitude. The paper gives a general geographical description of the relief, geology, and hydrography of Northern Ontario, and deals especially with its resources in the way of minerals, agricultural land, fisheries, and forests.

The principal rivers and lakes of what is now Northern Ontario were surveyed topographically and geologically by myself in the thirty-one years from 1869 to 1900 inclusive, and they have been described in various summary and detailed reports of the Geological Survey. Maps have been published showing Lake Nipigon, the country around Thunder Bay, the whole of the basin of Moose River, the Sudbury district,

and the region around French River. The maps resulting from many of my surveys have not yet been published, although on file in the office of the Geological Survey, and accessible to anyone requiring them. In 1900 the Government of Ontario sent out ten surveyors, in charge of an equal number of parties, to inspect Northern Ontario. The reports of these surveyors and explorers, recently published in one volume, amply confirm all that I have said during the last thirty years, in the Geological Survey reports and elsewhere, in regard to the 'New Ontario.' A small-scale map, compiled from the most recent surveys and explorations, accompanies the paper.

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6. *On the Systematic Exploration of the Atmosphere at Sea by means of Kites. By* A. LAWRENCE ROTCH, *Director of Blue Hill Meteorological Observatory (Massachusetts, U.S.A.) and American Member of the International Aëronautical Committee.*

It is appropriate that this paper should be presented at Glasgow, since it was here that Dr. Alexander Wilson first used kites for meteorological observations in 1749.[1]

Kite-flying with continuously recording instruments was originated at Blue Hill in 1894, and the progress of the work is set forth in five annual reports presented to Section A of this Association. Although the meteorological conditions up to a height of three miles above this region have been ascertained by several hundred kite-flights, yet since wind of at least twelve miles an hour is required, certain types of weather—notably the anticyclonic—can rarely be studied.

The method proposed not only permits kites to be flown in calm weather, but enables data to be obtained a mile or two above the oceans, where no observations have been possible hitherto. The method consists in installing the kites and apparatus on board a steamship, which, when travelling through calm air at a speed of ten or twelve knots per hour, enables the kites and instruments to be raised to the height that can be reached in the most favourable wind. Should the wind be too strong, its force may be moderated by steaming with it. In this way the kites can be flown at all times and in the equatorial regions, where a knowledge of the conditions of the upper atmosphere is needed to complete our theories of the atmospheric circulation.

The use of kites to the best advantage requires a vessel that can be manœuvred at will, and therefore experiments were made in Massachusetts Bay on a tug having a maximum speed of ten miles an hour. Although the wind blew only six to ten miles an hour, and at no time was strong enough to lift the kites, yet by steaming towards it within 45° of its mean direction, the meteorograph was raised to a height of half a mile. The ease with which the kites were launched and the steadiness with which they flew in the uniform artificial wind were noticeable. A trial of the kites was next made upon a passenger steamer crossing the North Atlantic in order to ascertain whether it was possible to obtain in this way meteorological data frequently during the voyage. Flights were made on five days, when although the winds accompanying an anticyclone were too light to lift the kites, the artificial wind, caused by the eastward motion of the vessel at a speed of 15 knots, sufficed to carry the kites and meteorograph to a maximum height of one-third of a mile. Had it been possible to alter the course of the vessel the kites could have been flown every day. The kite records obtained in this anticyclone, in connection with similar ones on deck, show abnormal changes of temperature with altitude above the ocean, great fluctuations in relative humidity, and slight variations in wind velocity. A series of such flights on successive voyages would disclose any difference in the vertical distribution of the meteorological elements above the ocean as compared with that over the land, and in weather conditions like the above would furnish data for the upper air that cannot be obtained with kites at a fixed station.

[1] *Trans. Roy. Soc. Edinburgh*, vol. x. part ii. pp. 284–286.

7. *Report on Changes of the Land-level of the Phlegræan Fields.*
See Reports, p. 382.

TUESDAY, SEPTEMBER 17.

The following Papers were read:—

1. *Weather Maps. By* W. N. SHAW, *F.R.S.*

The author exhibited a set of specimens of the daily weather reports issued by different European and extra-European countries in 1901. The maps of the following countries were shown:—

EUROPEAN.	EXTRA-EUROPEAN.
Austria.	Algeria.
Bavaria.	Australasia.
Belgium.	Canada.
British Isles.	India.
Denmark.	„ Bay of Bengal.
France.	Japan.
Germany.	Mexico.
Holland.	United States.
Italy.	
Portugal.	
Roumania.	
Russia.	
Saxony.	
Spain.	
Switzerland.	

2. *The National Antarctic Expedition. By* Dr. J. SCOTT KELTIE.

3. *With the 'Discovery' to Madeira. By* Dr. H. R. MILL, *F.R.S.E.*

4. *The Methods and Plans of the Scottish National Antarctic Expedition. By* W. S. BRUCE.

5. *The Experimental Demonstration of the Curvature of the Earth's Surface. By* H. YULE OLDHAM, *M.A.*

In 1870 Dr. A. R. Wallace performed his well-known Bedford Level experiment. In the summers of 1900 and 1901 a series of similar experiments was made with the special object of obtaining photographic records of the same. The Bedford Level is a portion of the Fens north of Ely, through which in the seventeenth century two great canals were made, shortening the course of the Ouse. Of these, one, the New Bedford river, is tidal; the other, the old Bedford river, has locks at each end, and presents long, straight stretches of water without current or tide. The six-mile stretch of the old Bedford river between Welney

and Denver was selected, as it is perfectly straight, has a bridge at each end, but none in between. The height of the parapet of Welney bridge above the water level was measured, a mark was set up on Denver bridge at the same height above the water-level, and midway—three miles from each end—a mark was set up on a pole at the same height above the water-level. A telescope was then directed from the parapet of Welney bridge to the mark on Denver bridge, and the middle mark was seen to stand up about six feet above the line of sight, agreeing with the effect calculated to be produced by the curvature of the earth's surface.

6. *Travels in China.* *By* R. LOGAN JACK, *LL.D., F.R.G.S.*

The party, consisting, besides the writer, of his son R. Lockhart Jack and Mr. J. F. Morris, employed by an English capitalist who had obtained mining concessions in Szechuan, left Shanghai on January 4, 1900.

Having reached Ichang (1,000 miles) by steamers up the Yangtse, a houseboat was chartered by which the party made the voyage to Chung King, a further distance of 392 miles.

An overland journey of 299 miles was then made to Chengtu, the capital of Szechuan, *via* the coal mines of Lung Chang and the brine wells of Nei-Kiang-Hsien.

The party had occasion to cross five times the Chengtu Plain, whose fertility, enhanced by a perfect system of irrigation, enables it to support four million inhabitants. They visited and mapped the valley of Tung-ling-tse, where copper mines are worked by the Chinese, and made a 'loop-cast' of 607 miles to the 'Northern Alps,' at first through a large tract of undescribed country and afterwards over Gill's route of 1877, *via* Lung-an and Sungpan.

Leaving Chengtu on June 19, this time accompanied by Mr. Herbert Way, who represented an English company, the party travelled by road (350 miles) to the Maha Gold Mines, which overlook the left bank of the Ya-lung River. Here their stay was cut short by long-delayed communications from Chung King relating the capture of the Taku forts, the tragedies of Tientsin, and the supposed massacre of all foreigners at Pekin. The British Consul at Chung King 'most strongly advised' the party to make for Burma.

An attempt was made to reach Kampti, on the Upper Irrawadi, by the route followed by Prince Henri of Orleans, and the party got as far as Hsiao Wei-si, on the Mekong, where a French missionary related some of Prince Henri's experiences and demonstrated the uselessness of the attempt so late in the season. It was judged imprudent to run such risks. Nine days after leaving Maha the party were the guests of a Lolo chieftain, the Toussa of Kwa-pit. Between the Yangtse and the Mekong extra precautions had to be taken in crossing a pass infested by robbers armed with crossbows and poisoned arrows.

Very unwillingly, the party, whose leading idea was to keep as much as possible among the Lolo aborigines and half-Tibetan Sifan tribes, retraced their steps, and leaving the Yangtse at Shi-Ku made for Sin Kai or Bhamo, a route which brought them again into contact with the Chinese. They crossed the Mekong and Salwen Rivers, and finally reached Bhamo, in Upper Burma, on October 21, after overcoming many obstacles. At Yung-chang further progress seemed to be barred by the refusal of the Carriers' Union to transport the baggage of foreigners, and the tales which the coolies had been told of the terrors of the 'fever valley' (Salwen) had so demoralised them that they were with difficulty prevented from deserting in a body.

Interesting observations were made on the Lolos and Sifans, as well as on the Shan tribes of the Tai-ping Valley and the Katchins of the mountain regions on the border of Burma. The distance from Maha to Myothet on the Irrawadi, was estimated at 874 miles.

The journey afforded opportunities of mapping, to some extent, the margin of the Chengtu Plain and the rivers which fall into it from the north. Portions of the courses of the Ya-lung and Yangtse, near Kwa-pit and Li-Kiang respectively,

were also laid down with more definiteness than had previously been attained. These rivers both make remarkable bends which are not given in any European map.

A number of views, by Mr. R. Lockhart Jack and others, illustrative of the journey were exhibited by the aid of the lantern.

7. *The Crux of the Upper Yangtse.* *By* ARCHIBALD LITTLE.

8. *The Representation of the Heavens in the Study of Cosmography.* *By* A. GALERON.

Section F.—ECONOMIC SCIENCE AND STATISTICS.

President of the Section—Sir Robert Giffen, K.C.B., F.R.S.

THURSDAY, SEPTEMBER 12.

The President delivered the following Address:—

The Importance of General Statistical Ideas.

I trust you will excuse me, on an occasion like the present, for returning to a topic which I have discussed more than once—the utility of common statistics. While we are indebted for much of our statistical knowledge to elaborate special inquiries such as were made by Mr. Jevons on prices and the currency, or have lately been made by Mr. Booth into the condition of the London poor, we are indebted for other knowledge to continuous official and unofficial records, which keep us posted up to date as to certain facts of current life and business, without which public men and men of business, in the daily concerns of life, would be very much at a loss. What seems to me always most desirable to understand is the importance of some of the ideas to be derived from the most common statistics of the latter kind—the regular records of statistical facts which modern societies have instituted, especially the records of the census, which have now existed for a century in most European countries and among peoples of European origin. Political ideas and speculation are necessarily coloured by ideas originating in such records, and political action, internationally and otherwise, would be all the wiser if the records were more carefully observed than they are, and the lessons to be derived widely appreciated and understood.

I propose now to refer briefly to one or two of these ideas which were taken up and discussed on former occasions,[1] and to illustrate the matter farther by a reference to one or two additional topics suggested in the same manner, and more particularly by the results of the last census investigations, which complete in this respect the record of what may be called the statistical century *par excellence*—the century which has just closed.

Increase of European Population during last Century.

The first broad fact then of this kind, which I have discussed on former occasions, is the enormous increase of the population of European countries and of peoples of European origin during the century just passed, especially the increase of the English people and of the United States, along with the comparative stationariness of the population of one or two of the countries, particularly France, at the same time. The growth all round is from about 170 millions at the beginning of the century to about 510 millions (excluding South American countries and Mexico); while the growth of the United States alone is from a little over 5 to nearly 80 millions, and of the English population of the British Empire from about 15 to 55 millions. Germany and Russia also show remarkable growth—

[1] Cf. *Essays in Finance*, 2nd series, pp. 275-364, and *Proceedings of Manchester Statistical Society*, October 17 1900.

from 20 to 55 millions in the one case, and from 40 to 135 millions in the other—partly due to annexation; but the growth of France is no more than from 25 to 40 millions. Without discussing it, we may understand that the economic growth is equally if not more remarkable. The effect necessarily is to assure the preponderance of European peoples among the races of the world—to put aside completely, for instance, the nightmares of yellow or black perils arising from the supposed overwhelming mass of yellow or black races, these races by comparison being stationary or nearly so. The increase of population being continuous, unless some startling change occurs before long, each year only makes European preponderance more secure. Equally it follows that the relative position of the English Empire, the United States, Russia, and Germany has become such as to make them exclusively the great world powers, although France, for economic reasons, notwithstanding the stationariness of its population, may still be classed amongst them. When one thinks what international politics were only a hundred years ago—how supreme France then appeared; how important were Austria, Italy, Spain, and even countries like Holland, Denmark, and Sweden—we may surely recognise that with a comparatively new United States on the stage, and with powers like Russia and Germany come to the front, the world is all changed politically as well as economically, and that new passions and new rivalries have to be considered.

The figures also suggest that for some time at least the movements going on must accentuate the change that has occurred. According to the latest figures, there is no sign that either in France or any other European country which has been comparatively stationary has any growth of population commenced which will reverse the change, while a large increase of population goes on in the leading countries named. This increase, it is alleged, is going on at a diminishing rate—a point to be discussed afterwards—but in the next generation or two there is practically no doubt that the United States will be a larger international factor than it is, both absolutely and relatively, and that Russia, Germany, and the English people of the British Empire will also grow, though not in such a way, apparently, as to prevent the greater relative growth of the United States, and notwithstanding perhaps some relative changes of a minor character amongst themselves.

The foreign nations then with which the British Empire is likely to be concerned in the near future are Russia, Germany, and the United States; and other Powers, even France, must more and more occupy a second place, although France, for the moment, partly in consequence of its relations with Russia, occupies a special place.

Special Position of British Empire.

Another idea which follows from a consideration of the same facts is the necessity laid upon the British Empire to consolidate and organise itself in view of the large additions of subject races made to it in the last century, and especially in the last twenty years of the century. In a paper which I read before the Royal Colonial Institute two years ago, an attempt was made to show that the burden imposed on the white races of the Empire by these recent acquisitions was not excessive as far as the prospect of internal tumults was concerned. Relatively to some other Powers, especially France, we have also been gaining internationally in strength and resources. But whether we had gained internationally on the whole, looking at the growth of Powers like Russia, the United States, and Germany, and their greater activity in world-politics, was a different question. The problem thus stated remains. It would be foreign to the scope of an address like this, which must avoid actual politics, to examine how far light has been thrown on it by the South African war. No one can question at least that the organisation of the Empire must be governed by considerations which the international statistics suggest, and that no step can be taken safely and properly unless our public men fully appreciate the ideas of international strength and resources as well as other considerations which are germane to the subject.

Europe and Foreign Food Supplies.

Another idea to which attention may be drawn appears to be the increasing dependence of European nations upon supplies of food and raw material obtained from abroad. We are familiar with a conception of this kind as regards the United Kingdom. For years past we have drawn increasing supplies from abroad, not merely in proportion to the growth of population, but in larger proportion. The position here obviously is that, with the industries of agriculture and the extraction of raw material (except as regards the one article, coal) practically incapable of expansion, and with a population which not only increases in numbers, but which becomes year by year increasingly richer per head, the consuming power of the population increases with enormous rapidity, and must be satisfied, if at all, by foreign imports of food and raw materials; there is no other means of satisfaction. But what is true of the United Kingdom is true in a greater or less degree of certain European countries—France, the Low Countries, the Scandinavian countries, Austria-Hungary, Italy, and Germany. Especially is it true in a remarkable degree of Germany, which is becoming increasingly industrial and manufacturing, and where the room for expansion in agriculture is now very limited. Those interested in the subject may be referred to an excellent paper by Mr. Crawford, read at the Royal Statistical Society of London about two years ago. What I am now desirous to point out is the governing nature of the idea, which necessarily follows from the conception of a European population living on a limited area, with the agricultural and extractive possibilities long since nearly exhausted, and the population all the time increasing in numbers and wealth. Such a population must import more and more year by year, and must be increasingly dependent on foreign supplies.

I shall not attempt to do over again what is done in Mr. Crawford's paper, but a few figures may serve to illustrate what is meant. In the 'Statistical Abstract' for the principal and other foreign countries I find tables for certain European countries classifying the imports for a series of years into articles of food, raw and semi-manufactured articles, &c. From these I extract the following particulars for all the countries which have tables in this form:—

Imports of Articles of Food and Raw Materials and Semi-manufactured Articles into the undermentioned Countries in 1888 and 1898 compared.

—		1888	1898	Increase	
				Amount	Per Cent.
Articles of Food, &c.					
Russia . .	1,000 roubles	78,975	105,391	27,416	35
German Empire	mln. marks	907	1,819	912	100
France . .	1,000 francs	1,503,000	1,505,000	Nil	Nil
Switzerland .	,,	238,000	332,000	94,000	40
Italy . .	1,000 lire	274,480	391,600	117,120	42
Austria-Hungary	1,000 gulden	(1891) 108,441	191,919	92,478	85
Raw and Semi-manufactured Materials.					
Russia . .	1,000 roubles	241,497	313,629	71,132	29
German Empire	mln. marks	1,507	2,247	740	49
France . .	1,000 francs	2,014	2,348	334	16
Switzerland	,,	308,110	390,111	82,001	27
Italy . .	1,000 lire	398,330	509,418	111,088	28
Austria-Hungary	1,000 gulden	231,000	293,000	62,000	27

The drawback to this table is that it is one of values. Consequently the increase of values in the later years may in part be one of values only without corresponding increase of quantities. But the general course of prices in the period in question was not such as to cause a great change of values apart from a change in quantities. The inference seems undeniable, then, that the Continental countries named, especially Germany, have largely increased their imports of food and raw materials of recent years—that is, have become increasingly dependent on foreign and oversea supplies. The position of Germany, with its enormous increase of food imports—from 907 to 1,819 million marks, or from 45 to over 90 million sterling, and its corresponding increase of raw material imports—from 1,507 to 2,247 million marks, or from 75 to 112 million sterling—is especially remarkable.

An examination in detail of the quantities imported of particular articles would fully confirm the impression given by the summary figures. But it may be enough to refer to the 'Statistical Abstract' from which I have been quoting, as well as to Mr. Crawford's paper. The figures are not out of the way in any respect, and it is the idea we have now to get hold of.

The inference is that the difference between the United Kingdom and Continental countries, especially Germany, as regards dependence on foreign supplies of food and raw materials, is only one of degree, and that, as regards Germany at least, the conditions are already remarkably like those of the United Kingdom, while the more rapidly Germany increases its manufacturing and industrial population, the more like it will become to this country. In other words, in the future there will be two great countries, and not one only, dependent largely for their food and raw materials on supplies from abroad. What their position is to be economically and otherwise relatively to the United States, which is at once the main source of supply, and a competitor with European countries in manufactures, is obviously a matter of no little interest. As a believer in free trade, I am sure that nothing but good will come to all the countries concerned if trade is interfered with as little as possible by tariffs and Government regulations. I believe, moreover, that the practice of free trade, whatever their theories may be, will unavoidably be accepted by all three countries before long. Obviously, however, as the new tariff in Germany indicates, there is to be a great struggle in that country before the situation is accepted; and if some people in this country had their way, notwithstanding our long experience of free trade and its blessings, we should even have a struggle here.

There is another point of view from which the facts should be studied. We are accustomed, and rightly so, I think, to consider naval preponderance indispensable to the safety of the Empire, and especially indispensable to the safety of the country from blockade, and from the interruption of its commerce, which would be our ruin. But our position in this respect is apparently not quite exceptional. Less or more our Continental neighbours, and especially Germany, are in the same boat. In the event of war, if they could not make up the loss by traffic over their land frontiers, they would be just as liable to suffer from blockade and interrupted commerce as we are. It is conceivable, moreover, that in certain wars some of the countries might not be able to make up by traffic over their land frontiers for blockade or interruption of commerce by sea. We may apprehend, for instance, that Germany, if it were victorious by sea in a war with France, would insist upon Belgium and Holland on one side, and Italy and Spain on the other side, not supplying by land to France what had been cut off by sea. One or [illegible]

[illegible] up to Germany by [illegible] had been cut off by sea. Germany in this view, apart from any possibility of rupture with this country, has a case for a powerful fleet. It is not quite so much liable to a blockade as we are, but there is a liability of the same kind. The question of naval preponderance among rival powers may thus become rather a serious one. If preponderance is to be nearly as essential to Germany as it is to this country, who is to preponderate? What our practical action ought to be in

the premises is a question that might easily lead us too far on an occasion like this, but the facts should be ever present to the minds of our public men. We may be quite certain that they are quite well known and understood in the councils of the Russian, German, French, and other Continental Governments.

New Population and New Markets.

Another idea suggested by the facts appears to be an answer to the question as to how new markets are to be found for the products of an increasing population—a question which vexes the mind of many who see in nothing but foreign trade an outlet for new energies. The point was mentioned in my address at Manchester a year ago, but it deserves, perhaps, a more elaborate treatment than it was possible then to give it. What we see then is that not only in this country, but in Germany and other Continental countries, millions of new people are, in fact, provided for in every ten years, although the resources of the country in food and raw materials are generally used to the full extent, and not capable of farther expansion, so that increasing supplies of food and raw material have to be imported from abroad. How is the thing done? Obviously the main provision for the wants of the new people is effected by themselves. They exchange services with each other, and so procure the major part of the comforts and luxuries of life which they require. The butcher, the baker, the tailor, the dressmaker, the milliner, the shoemaker, the builder, the teacher, the doctor, the lawyer, and so on, are all working for each other the most part of their lives, and the proportion of exchanges with foreign countries necessary to procure some things required in the general economy may be very small. These exchanges may also very largely take the form of a remittance of goods by foreign countries in payment of interest on debts which they owe, so that the communities in question obtain much of what they want from abroad by levying a kind of rent or annuity which the foreigner has to pay. If more is required, it may be obtained by special means, as, for instance, by the working of coal for export, which gives employment in this country to about 200,000 miners, by the employment of shipping in the carrying trade, by the manufacture of special lines of goods, and so on. But the main exchanges of any country are, and must be, as a rule, at home, and the foreign trade, however important, will always remain within limits, and bearing some proportion to the total exchanges of the country. Hence, when additions to the population, and how they are to live, are considered, the answer is that the additions will fill up proportionately the framework of the various industries already in existence, or the ever-changing new industries for home consumption which are always starting into being. These are the primary outlets for new population even in old countries like the United Kingdom and Germany. Of course, active traders and manufacturers, each in his own way, are not to take things for granted. They must strive to spread their activities over foreign as well as over home markets. But looking at the matter from the outside, and scientifically, it is the home and not the foreign market which is always the most important.

The same may be said of a country in a somewhat different economic condition from England and Germany, viz., the United States. I can only refer to it, however, in passing, as the facts here are not so clearly on the surface. Contrary to England and Germany, which have no food resources and resources of raw material capable of indefinite expansion, the United States is still to a large extent a virgin country. Its increasing population is therefore provided for in a different way for the most part from the increase in England and Germany. But even in the United States it has been noticeable at each of the last census returns that the increasing population finds an outlet more and more largely, not in agriculture and the extraction of raw materials, but in the miscellaneous pursuits of industry and manufacture. The town population increases disproportionately. In the last census especially it was found that the overflow of population over the far Western States seemed to have been checked, the increase of population being

mainly in the older States and the towns and cities of the older States. The phenomena in England and Germany and in other Continental countries are accordingly not singular. The older countries, and the older parts even of a new country like the United States are becoming more and more the centres where populations live and grow, because they are the most convenient places for the general exchange of services with each other among the component parts of a large population, which constitutes production and consumption. A small expenditure of effort in proportion enables such communities to obtain from a distance the food and raw materials which they require. Migration is no longer the necessity that it was.

Decline in Rate of Growth of Population.

I come now to another idea appearing on the surface of the census returns when they are compared for a long time past, and the connected returns of births, marriages, and deaths, which have now been kept in most civilised communities for generations. Great as the increase of population is with which we have been dealing, there are indications that the rate of growth in the most recent census periods is less in many quarters than it formerly was, while there has been a corresponding decline in the birth-rates; and to some extent, though not to the same extent, in the rate of the excess of births over deaths, which is the critical rate of course in a question of the increase of population. These facts have suggested to some a question as to how far the increase of population which has been so marked in the past century is likely to continue, and speculations have been indulged in as to whether there is a real decline in the fecundity of population among the peoples in question resembling the decline in France, both in its nature and consequences. I do not propose to discuss all these various questions, but rather to indicate the way in which the problem is suggested by the statistics, and the importance of the questions thus raised for discussion, as a proof of the value of the continuous statistical records themselves.

The United States naturally claims first attention in a matter like this, both on account of the magnitude of the increase of population there, and the evidence that recent growth has not been quite the same as it was earlier in the century. Continuing a table which was printed in my address as President of the Statistical Society, in 1882, above referred to, we find that the growth of population in the United States since 1800 has been as follows in each census period:—

Population in the United States, and Increase in each Census Period of the Nineteenth Century.

—	Population	Increase since previous Census	
		Amount	Per Cent.
	Millions	Millions	
1800 . . .	5·3	—	—
1810 . . .	7·2	1·9	36
1820 . . .	9·6	2·4	33
1830 . . .	12·9	3·3	34
1840 . . .	17·1	4·2	33
1850 . . .	23·2	6·1	36
1860 . . .	31·4	8·2	36
1870 . . .	38·5	7·1	23
1880 . . .	50·1	11·6	30
1890 . . .	62·6	12·5	25
1900 . . .	75·7[1]	13·1	21

[1] This does not include population of Indian reservations, &c., now included in the official census for the first time.

Thus it is quite plain that something has happened in the United States to diminish the rate of increase of population after 1860. Up to that time the growth in each census period from 1800 downwards had ranged between 33 and 36 per cent. Since then the highest rates have been 30 per cent. between 1870 and 1880, and 25 per cent. between 1880 and 1890. There is a suspicion, moreover, that, owing to errors in the census of 1870, which were corrected in 1880, the increase between 1870 and 1880 was not quite so high as stated. There is accordingly a somewhat steep decline from a growth in each ten years prior to 1860, ranging between 33 and 36 per cent., to a growth first of about 25 per cent., and finally of 21 per cent. only. The Civil War of the early sixties naturally occurs to one as the explanation of the break immediately after 1860, but the effects could hardly have continued to the present time, and a more general explanation is suggested.

Other special explanations have occurred to me as partly accounting for the change. One is that, prior to 1860, the United States at different times increased its territory and population partly by purchase and partly by annexation. But I cannot make out that either the purchase of Louisiana early in the century, or the subsequent annexations following the Mexican war, would make a material difference. There is a considerable increase certainly after the Mexican war, but it would be difficult indeed to estimate how much of the population of Texas and New Mexico, which was then added to the Union, had previously swarmed over from the Union, and had thus been from the first economically, if not politically, part of the United States. Another obvious suggestion is that possibly immigration into the United States has fallen off as compared with what it formerly was. But this explanation also fails, as far as the official figures carry us. The proportion of immigration to the total increase of population in each census period since 1820, previous to which I have not been able to obtain figures, has been as follows:—

Proportion of Immigration to Total Increase of Population in the undermentioned Periods in the United States.

	Per Cent.		Per Cent.
1820–30	4·7	1860–70	35·0
1830–40	14·2	1870–80	24·2
1840–50	27·9	1880–90	42·1
1850–60	31·5	1890–1900	29·4

Immigration, according to these figures, has thus in late years played as important a part as it formerly did in the increase of population in the United States. Possibly the official figures of immigration of late years are a little exaggerated, as the United States Government does not show a balance between immigration and emigration; but whatever corrections may be made on this account, the recent figures of immigration are too large to permit the supposition that the failure of immigrants accounts in the main for the diminished rate of increase of the population generally. The ten years' percentage of increase without immigrants, I may say, varied before 1860 between 24 and 32 per cent., and has since fallen to 14 and 15 per cent. Even if the latter figures should be increased a little to allow for the over-estimate of immigration, the change would be enormous.

Passing from the United States, we meet with similar phenomena in Australasia. Indeed, what has happened in Australasia of late has been attracting a good deal of attention. The following short table, which is extracted from the statistics of Mr. Coghlan, the able statistician of the Government of New South Wales, gives an idea of what has occurred:—

Population of Australasia at different Dates, with the Annual Increase per Cent. in each Period.

—	Population	Annual Increase per Cent. since previous Date	—	Population	Annual Increase per Cent. since previous Date
	Thousands			Thousands	
1788 . .	1·0	—	1851 . .	430·6	7·36
1801 . .	6·5	15·13	1861 . .	1,253·0	11·30
1811 . .	11·5	11·91	1871 . .	1,924·8	4·39
1821 . .	35·6	5·88	1881 . .	2,742·5	3·60
1831 . .	79·3	8·34	1891 . .	3,809·9	3·34
1841 . .	211·1	10·28	1899 . .	4,483·0	2·1

Supplementary Table of Rate per Cent. of Increase since 1890.

	Per Cent.		Per Cent.
1891	3·34	1896	1·84
1892	2·10	1897	1·86
1893	1·96	1898	1·40
1894	1·95	1899	1·44
1895	1·88		

The decline in the rate of increase is so great and palpable as to need no comment.

Here the perturbations due to immigration have obviously been greater than in the case of the United States. The country was, in fact, settled mainly between 1850 and 1870, without previously having had a population to speak of. But deducting immigration, the increase would appear to have been as follows in each decade:—

Rate of Increase per Cent. of Population in Australasia, deducting Immigration, in the undermentioned Periods.

	Per Cent.		Per Cent.
1851–60	48·5	1880–90	24·5
1860–70	30·0	1890–99	16·0
1870–80	25·0		

Of course, so long as immigration continues, the effect is to swell indirectly the natural increase of population, so that the large increases here shown between 1851 and 1870, and even down to 1890, may be accounted for in part as the indirect result of the large immigration that was going on. But whatever the cause, the fact is unmistakable that the rate of increase, apart from the direct immigration, has declined just as it has done in the United States.

There has been a similar though not nearly so marked a decrease in England, at any rate if we carry the comparison back to the period before 1850. The population at each census period since 1800 in England, with the percentage increase between each census period, have been as follows:—

Population of England at the Date of each Census since 1800, *with Percentage of Increase between each Census.*

—	Population	Increase per Cent. since previous Census	—	Population	Increase per Cent. since previous Census
	Millions.			Millions.	
1800 .	8·9	—	1860 .	20·1	11·9
1810 .	10·2	14·0	1870 .	22·7	13·2
1820 .	12·0	18·1	1880 .	26·0	14·4
1830 .	13·9	15·8	1890 .	29·0	11·6
1840 .	15·9	14·5	1900 .	32·3	12·2
1850 .	17·9	12·9			

Thus the increase between recent census periods has been sensibly less than it was before 1850; and the slight recovery between 1860 and 1880 has not been maintained. We are thus in presence of much the same kind of change as has been shown in the United States and in Australasia.

It should be noted, however, in order that we may not strain any fact, that, when the United Kingdom is viewed as a whole, Scotland and Ireland, as well as the senior partner, being taken into account, it cannot be said that there is any falling off in the rate of growth of the population since 1850. For several decades after that, in fact, the rate of growth of the United Kingdom as a whole was diminished enormously by the emigration from Ireland, and the growth since 1860 has been at a greater rate than in the thirty years before. There may be new causes at work which will again diminish the rate of growth, but in a broad view they do not make themselves visible owing to the disturbance caused by the Irish emigration. Still the facts as to the United Kingdom as a whole ought not to prevent us from considering the facts respecting England only along with the similar facts respecting the United States and Australasia.

These diminutions in the rate of growth of large populations, as I have indicated, are corroborated by a study of the birth-rates, and of the rate of the excess of births over deaths.

The United States unfortunately is without birth- or death-rates, owing to the want of a general system of registration over the whole country. This is a most serious defect in the statistical arrangements of that great country, which it may be hoped will be remedied in time. In the absence of the necessary records I have made some calculations so as to obtain a figure which may be provisionally substituted for a proper rate of the excess of births over deaths, which I submit for what it may be worth as an approximation, and an approximation only. In these calculations one-tenth of the increase of population between two census periods, apart from immigration, is compared with the mean of the population at the two census dates themselves, with the following results:—

Approximate Rate of Excess of Births over Deaths in the United States, calculated from a Comparison of One-tenth the Increase of Population between the Census Periods, deducting Immigrants, with the Mean of the Numbers of the Population at the two Census Dates.

Year	1 Population	2 Mean of Population between two Censuses	3 One-tenth of increase since previous Census, less Immigrants	4 Calculated Excess of Births over Deaths per 1,000, proportion of Col. 3 to Col. 2
	Millions.	Millions.	Thousands.	
1800 .	5·3	...	—	—
1810 .	7·2	6·2	—	—
1820 .	9·6	8·4	...	...
1830 .	12·9	11·2	308	28
1840 .	17·1	15·0	360	24
1850 .	23·2	20·1	441	22
1860 .	31·4	27·3	565	21
1870 .	38·5	35·0	462	13
1880 .	50·2	44·4	878	20
1890 .	62·6	56·4	722	13
1900 .	75·7	69·2	923	13

Thus, while the excess rate was as high as 21 to 28 per 1,000 before 1860, it has since fallen to one of 13 only, or about one-half. Whatever validity may attach to the method of calculation, the real facts would no doubt show a change in the direction of the table—a decline in the rate of the excess of births over deaths from period to period. The decline in the growth of population is thus not merely the direct effect of a change in immigration, but is connected with the birth-

and death-rates themselves, although these rates are of course indirectly affected by the amount and proportion of immigration. It would be most important to know what the decline in the birth-rate is by itself, and how far its effects on the growth of population have been mitigated or intensified by changes in the death-rate; but United States records generally give no help on this head.

Dealing with Australasia in the same way, we have the advantage of a direct comparison of both birth- and death-rates and the rate of the excess of births over deaths. This is done in the following table:—

Birth-rate and Death-rate and Rate of Excess of Births over Deaths in Australasia for undermentioned Years.

[From Mr. Coghlan's statistics.]

—	Birth-rate	Death-rate	Excess of Births over Deaths
1861–65	41·92	16·75	25·17
1866–70	39·84	15·62	24·22
1871–75	37·34	15·26	22·08
1876–80	36·38	15·04	21·34
1881–85	35·21	14·79	20·42
1886–90	34·43	13·95	20·48
1891–95	31·52	12·74	18·78
1896–99	27·35	12·39	14·96

Thus from a high birth-rate forty years ago Australasia has certainly gone down to very ordinary birth-rates, lower than in the United Kingdom and in Continental countries, and Australasia certainly has had heavy declines in the rate of excess of births over deaths, viz., from 25·17 in 1861–65 to 15 in 1896–99, which is to be compared with the decline in the United States, as above stated approximately, from 28 in 1820–30, and 21 as late as 1860, to 13 in the last twenty years.

A similar table for England only gives the following results:—

Birth-rate and Death-rate and Rate of Excess of Births over Deaths in England for undermentioned Years.

	Birth-rate per 1,000	Death-rate per 1,000	Excess of Birth-rate over Death-rate
1851	34·2	22·0	12·2
1861	34·6	21·6	13·0
1871	35·0	22·6	12·4
1881	33·9	18·9	15·0
1891	31·4	20·2	11·2
1899	29·3	18·3	11·0

Note.—Highest birth-rate in 1876, 36·3.

Here the birth-rates, to begin with, are not so high as in Australasia, and presumably in the United States, and the excess of births over deaths, though it has declined a good deal since 1871–81, when it was highest, has been by comparison fairly well maintained, being still 11 per 1,000, as compared with 12·2 in 1851.

We have thus on one side a manifest decline in the rate of growth of population in three large groups of population, coupled with a large decline of birth-rates in England and Australasia where the facts are known, and a smaller decline in the rate of the excess of births over deaths, this decline in England as yet being comparatively small. Such facts cannot but excite inquiry, and it is an excellent

result of the use of continuous statistical records that the questions involved can be so definitely raised.

As I have stated, it would be foreign to the object of this paper to discuss fully the various questions thus brought up for discussion, but one or two observations may be made having regard to some inferences which are somewhat hastily drawn.

1. The rate of growth of population of the communities may still be very considerable, even if it is no higher than it has been in the last few years. A growth of 16, 15, or even 12 per cent. in ten years, owing to the excess of births over deaths, is a very considerable growth, though it is much less than the larger figures which existed in some parts forty or fifty years ago. What has happened in the United Kingdom is well worth observing in this connection. Since 1840 the population of the United Kingdom as a whole has increased nearly 60 per cent., although the increase in most of the decades hardly ever exceeded 8 per cent., and in 1840–50 was no more than 2½ per cent. The increase, it must be remembered, goes on at a compound ratio, and in a few decades an enormous change is apparent. The increase from about 170 to 510 millions in the course of the last century among European people generally, though it includes the enormous growth of the United States in those decades, when the rate of growth was at the highest, also includes the slower growth of other periods, and the slower growths of other countries. An addition of even 10 per cent. only as the average every ten years would far more than double the 500 millions in a century, and an increase to at least 1,500 millions during the century now beginning, unless some great change should occur, would accordingly appear not improbable.

2. Some of the rates of growth of population from which there has been a falling off of late years were obviously quite abnormal. I refer especially to the growth in Australasia between 1850 and 1880, and the growth in the United States prior to 1860. They were largely due to the indirect effect of immigration which has been already referred to.

The population to which immigrants are largely added in a few years, owing to the composition of the population, has its birth-rates momentarily increased and its death-rates diminished—the birth-rates because there are more people relatively at the child-producing ages, and the death-rates because the whole population is younger, than in older countries. It appears quite unnecessary to elaborate this point. The rates of the excess of births over deaths in a country which is receiving a large immigration must be quite abnormal compared with a country in a more normal condition, while a country from which there is a large emigration, such as Ireland, must tend to show a lower excess than is consistent with a normal condition. This explanation, it may be said, does not apply to England, since it is a country which has not been receiving a large immigration or sending out, except occasionally, a large emigration. England, however, must have been affected both ways by movements of this character. It received undoubtedly a large Irish immigration in the early part of last century, and in more recent periods the emigration in some decades, particularly between 1880 and 1890, appears to have been large enough to have a sensible effect on both the birth-rate and the rate of the excess of births over deaths. This effect would be continued down into the following decade, and the consideration is therefore one to be taken note of as accounting in part for the recent decline in birth-rates in England.

In addition, however, it is not improbable that there was an abnormal increase of population in the early part of last century, due to the sudden multiplication of resources for the benefit of a poor population which had previously tended to grow at a very rapid rate, and would have grown at that rate but for the checks of war, pestilence, and famine, on which Malthus enlarges. The sudden withdrawal of the checks in this view would thus be the immediate cause of the singularly rapid growth of population in the early part of last century. It is quite in accordance with this fact that a generation or two of prosperity, raising the scale of living, would diminish the rate of growth as compared with this abnormal development, without affecting in any degree the permanent reproductive energy of the people.

3. It is also obvious that one explanation of the decline in birth-rate, and of

the rate of the excess of births over deaths, may also be the greater vitality of the populations concerned, so that the composition of the population is altered by an increase of the relative numbers of people not in the prime of life, so altering the proportion of the people at the child-producing ages to the total. This would be too complex a subject for me to treat in the course of a discursive address. Nor would it explain the whole facts, which include, for instance, an almost stationary annual number of births in the United Kingdom for more than ten years past, notwithstanding the largely increased population. But the case may be one where a great many partial explanations contribute to elucidate the phenomena, so that this particular explanation cannot be overlooked.

4. There remains, however, the question which many people have rushed in to discuss—viz., whether the reproductive power of the populations in question is quite as great as it was fifty or sixty years ago. We have already heard in some quarters, not merely that the reproductive energy has diminished, but suggestions that the populations in question are following the example of the French, where the rate of increase of the population has almost come to an end. Apart, however, from the suggestions above made as to the abnormality of the increase fifty or sixty years ago, so that some decline now is rather to be expected than not, I would point out that the subject is about as full of pitfalls as any statistical problem can be, for the simple reason that it can only be approached indirectly, as there have been no statistical records over a long series of years showing the proportion of births to married women at the child-producing ages, distinguishing the ages, and showing at the same time the proportion of the married women to the total at those ages. Unless there are some such statistics, direct comparisons are impossible, and a good many of the indirect methods of approaching the subject which I have studied a little appear, to say the least, to leave much to be desired. We find, for instance, that a comparison has been made in Australasia between the number of marriages in a given year or years and the number of births in the five or six years following, which show, it is said, a remarkable decline in the proportion of births to marriages in recent years as compared with twenty or thirty years ago. It is forgotten, however, that at the earlier dates in Australasia, when a large immigration was taking place, a good many of the children born were the children of parents who had been married before they entered the country, while there are hardly any children of such parents at a time when immigration has almost ceased. The answer to such questions is in truth not to be rushed, and the question with statisticians should rather be how the statistics are to be improved in future, so that, although the past cannot be fully explained, the regular statistics themselves will in future give a ready answer.

5. One more remark may, perhaps, be allowed to me on account of the delicacy and interest of the subject. To a certain extent the causes of a decline in reproductive energy may be part and parcel of the improved condition of the population, which leads in turn to an increase of the age at marriage, and an increase of celibacy generally through the indisposition of individual members of the community to run any risk of sinking in the scale of living which they may run by premature marriage. These causes, however, may operate to a great extent upon the birth-rate itself without diminishing the growth of population, because the children, though born in smaller proportion, are better cared for, and the rate of excess of births over deaths consequently remains considerable, although the birth-rate itself is low. The serious fact would be a decline of the rate of the excess of births over deaths through the death-rate remaining comparatively high while the birth-rate falls. It is in this conjunction that the gravity of the stationariness of population in France appears to lie. While the birth-rate in France is undoubtedly a low one, 21·9 per 1,000 in 1899, according to the latest figures before me, still this would have been quite sufficient to ensure a considerable excess rate of births over deaths, and a considerable increase of population every ten years if the death-rate had been as low as in the United Kingdom—viz., 18·3 per 1,000. A difference of 3·6 per 1,000 upon a population of about 40 millions comes to about 150,000 per annum, or 1,500,000 and rather more every ten years. In France, however, the death-rate was 21·1 per 1,000, instead

of 18·3, as in the United Kingdom, and it is this comparatively high death-rate which really makes the population stationary. The speculations indulged in in some quarters, therefore, though they may be justified in future, are hardly yet justified by the general statistical facts. The subject is one of profound interest, and must be carefully studied; but the conclusions I have referred to must be regarded as premature until the study has been made.

Conclusion.

Such are a few illustrations of the importance of the ideas which are suggested by the most common statistics—those of the regular records which civilised societies have instituted. It is, indeed, self-evident how important it is to know such facts as the growing weight of countries of European civilisation in comparison with others; the relative growth of the British Empire, Russia, Germany, and the United States, in comparison with other nations of Europe or of European origin; the dependence of other European countries as well as the United Kingdom upon imports of food and raw materials; the ability of old countries and of old centres in new countries to maintain large and increasing populations: and the evidence which is now accumulating of changes in the rate of growth of European nations, with suggestions as to the causes of the changes. It would be easy, indeed, to write whole chapters on some of the topics instead of making a remark or two only to bring out their value a little. It would also be very easy to add to the list. There was a strong temptation to include in it a reference to the relative growth of England, Scotland, and Ireland, which has now become the text of so much discussion regarding the practical question of diminishing the relative representation of Ireland in Parliament, and increasing that of England and Scotland. It is expedient, however, in an address like this, to avoid anything which verges on party politics, and I shall only notice that while the topic has lately become of keen interest to politicians, it is not new to statisticians, who were able long ago to foresee what is now so much remarked on. This very topic was discussed at length in the addresses of 1882-83, to which reference has been made, and even before that in 1876 it received attention.[1] Another topic which might have been added is that of the economic growth of the different countries which was discussed in the address in 1883; and such topics as the increase of population in a country like India under the peace imposed by its European conquerors, by which the stationariness of the country in numbers and wealth under purely native conditions has been changed, and something like European progress has been begun. Enough has been said, however, it may be hoped, to justify this mode of looking at statistics, and the ideas suggested by them.

May I once more, then, express the hope, as I have done on former occasions, that as time goes on more and more attention will be given to these common statistics and the ideas derived from them? The domination of the ideas suggested by these common figures of population statistics, in international politics and in social and economic relations, is obvious; and although the decline in the rate of growth of population in recent years, the last of the topics now touched on, suggests a great many points which the statistics themselves are as yet unfit to solve—what *can* be done with a great country like the United States, absolutely devoid of bare records of births, marriages, and deaths?—still the facts of the decline as far as recorded throw a great deal of light on the social and economic history of the past century, prepare the way for discussing the further topics which require a more elaborate treatment, and enforce the necessity for more and better records. We may emphasise the appeal, then, for the better statistical and economic education of our public men, and for the more careful study by all concerned of such familiar publications as the 'Statistical Abstracts,' the 'Statesman's Year-book,' and the like. The material transformations which are going on throughout the world can be substantially followed without any difficulty in such publications by those who have eyes to see; and to follow such transformations, so as to be ready for the practical questions constantly raised, is at least one of the main uses of statistical knowledge.

[1] See *Essays in Finance*, 2nd series, p. 290 *et seq.*; p. 330 *et seq.*; and 1st series, p. 280 *et seq.*

The following Papers were read:—

1. *The Postulates of the Standard.* *By* WILLIAM WARRAND CARLILE, *M.A.*

Professor Walker's exposition of the manner in which the standard substance comes to measure values in his 'Money Trade and Industry' shows the fallacy of the current view that any commodity can measure the value of any or of all others. We find, on the contrary, that the postulate of the whole process is this, that there must be a general desire for the substance which becomes the standard. Should this general desire cease to operate, the value-measuring process would cease also. This general desire must therefore be an insatiable desire. How it became so is a question that it is not proposed to enter on at present, but rather to look at the fact in some of its bearings. In connection with the Tabular Standard it seems clear that the natural gold standard must be, all the time, the basis of the prices whose average forms it. Being a mere secondary product, it could never be substituted for the primary. The conception of reality or objectivity depends upon human intercourse. Such sensations only give the impression of reality as are capable of exact comparison as between man and man. This applies also to the conception of value. For such exact comparison, however, a common meeting-ground for human desires is needed. This is furnished by the existence of one substance which is the general goal of industrial effort. The Austrian theory of decreasing degrees of utility ignores this. It has some application to expenditure on immediate consumption, but only a forced and unnatural one to business sales and purchases.

Though one must begin with the central fact of an insatiable desire for the standard substance, the next fact with which we are struck is its unlimited replaceability, for the purposes of money, by other substances. If a man has a document conveying to him the immediate right to gold on demand, the chances are a hundred to one that he will never ask for the gold itself at all. The document will serve all his purposes quite as well. Thus an immense mass of substitutes for gold comes into existence. But in all theories of demand and supply fluctuations in the supply of substitutes are held to affect the value of the original commodity just as much as fluctuations in its own supply; and so with the standard. The more completely inviolable, therefore, the gold standard is maintained by legislation, the more effective do these documents become as substitutes for gold, and the more, consequently, is the volume of money increased. This may be considered in connection with Jevons' metaphors of the two cisterns connected by a pipe, and of the two intersecting lines representing gold and silver respectively. The modern system connects all commodities by pipes into one great cistern called money, and neutralises all fluctuations. It really fulfils the ideal of the framers of systems of multiple tender. As a product of evolution, showing an interesting system of adaptation of means to ends, it is comparable to the human ear or the human eye.

2. *Some Notes on the Output of Coal from the Scottish Coalfields.* *By* ROBERT W. DRON, *A.M.Inst.C.E.*

During the last few years there has been a growing feeling of uneasiness regarding the duration of our coal supply, and there is at present a movement in favour of a further inquiry as to the extent of the coal resources of Great Britain.

The following considerations regarding the Scottish coalfield are in most cases applicable to the whole of Great Britain.

The output of coal in Great Britain in the year 1660 was about 2,000,000 tons per annum, and of that quantity Scotland probably produced about 250,000 tons. Since then there has been a steady progression, until now the Scottish output amounts to 31,142,612 tons per annum. The total quantity of coal which has been worked in Scotland up to the present date may be estimated at 1,600 million tons, and the quantity still to work at about 10,000 million tons.

During the last 400 years there have been many alarms regarding the approaching exhaustion of the coalfields, with the result that at various periods laws have been passed either totally prohibiting the exportation of coal or placing a heavy tax on any coal exported.

In recent years the proportion of the output which is exported has increased enormously. In 1861 the proportion of the output exported was only 6·4 per cent., whereas last year it amounted to over 20 per cent. In 1861 the home consumption per head of the population was about three tons per annum, whereas it is now over five tons per head of the population. Most of the Scottish coal exports go to the continent of Europe, and about 25 per cent. of the whole export goes to Germany.

If the export and home consumption are to continue increasing at the present rate, then by the end of this century the Scottish output will be 60 million tons per annum, and the 10,000 million tons we have available will be exhausted in about 180 years. If all the coalfields were producing coal in the same proportion to their area as in Lanarkshire, the output of Scotland would be 60,000,000 tons per annum. Such an output will never be required, because methods will be found to use the coal much more economically than at present, so that one ton of coal will do the work for which two tons are now required, and in that way the duration of the coalfields will be prolonged indefinitely. A great deal of coal is being wasted in the working, and in shafts and bores many thin seams are being passed through of which no national record is kept. There should be a Government department for the inspection of systems of working and for the preservation of exact records of all shafts and bores.

More than one-half of the Scottish output comes from the Lanarkshire coalfield, and at the present rate all the coals in that county will be exhausted in forty years; but within twelve or fifteen years all the thick and easily wrought seams of the Clyde basin will be worked out. This is not such a serious matter for the population of Glasgow and the west of Scotland as at first sight it might appear. The royalties payable on these coals are from 9*d.* to 1*s.* 6*d.* per ton higher than are payable on similar coals in the outlying districts. As the Lanarkshire coals become exhausted less money will be paid to the landlords and more to the railway companies, but the net result will not be any very serious increase in the cost of fuel.

The royalties at present being paid in Scotland vary from 2½*d.* to 2*s.* per ton, or on a sliding scale from $\frac{1}{14}$ to $\frac{1}{8}$ of the selling price. From the report of the Royal Commission on Mining Royalties it appears that the average royalty payable in Scotland in 1891 was 6·54*d.* per ton.

The average profit earned by the coalmasters under normal conditions is 8*d.* per ton.

Coal-cutting machines have been in use in Scotland for over thirty years, and last year 529,791 tons were produced by that method. It is not ignorance or prejudice which prevents the more extensive use of these labour-saving appliances, but the physical conditions under which most of the seams are now being worked. In practically every case where coal-cutting machinery can be used to advantage it has been adopted; but in the future it may come to be more largely used when thinner seams are opened up.

The annual output per man employed is 360 tons. In U.S. America it amounts to 400 tons, but in Germany it is only 270 tons per man.

The greatest depth from which coal is being worked in Scotland is 2,760 feet below the surface.

3. *The Growth and Geographical Distribution of Lunacy in Scotland. By* J. F. SUTHERLAND, *M.D.*

The lunacy forming the subject-matter of this communication is what is known as 'pauper lunacy,' an unfortunate and misleading term in so far as it refers to the lunacy arising in 80 per cent. of the population, whereas indigency, pauperism,

destitution, and delinquency account for about 10 per cent. of the population, and affluence for the remaining 10 per cent.

The maintenance of a pauper lunatic in an institution calls for an annual expenditure of 30*l.*, a sum beyond the reach of 80 per cent. of the population.

The lunacy statistics of the last two decades contrasted and the geographical distribution of lunacy (1901) set out (*vide* shaded map).

Between the lunacy ratios of the four main areas of Scotland with economic, ethnic, and geographical differences there are percentage differences respectively of 94, 72, and 62.[1]

Controversion of views put forward to the effect that lunacy is going up by leaps and bounds, views suggestive of a state of matters not without risk to the national well-being.

Acceptance of proposition that in large areas of country the lunacy ratio will not vary except within certain narrow limits.

Explanations of the enormous ratio differences as well as of the growth of lunacy are to be found in a consideration of the following five factors in the order of their respective importance.

First and most significant is the economic one suggestive of a widely different relative capacity on the part of householders in different counties to maintain the insane without the aid of the public purse in whole or in part.

Second.—The migration and emigration of the strong from rural and insular districts to centres of population results in the feeble products, mental and physical, of the birth-rate being left behind in, as a rule, stationary or dwindling populations.

Third.—The death-rate under 5, nearly three times greater in centres than in rural districts, has the effect of removing hundreds of lunatics who, had they survived the neglect, injudicious dieting, exanthematous diseases, &c., incidental to child life in industrial centres, would have augmented the statistics of lunacy in such centres (*vide* shaded map).

Fourth.—The conditions of modern life, with its unparalleled competition in every walk, abuse of alcohol and tea, errors of diet, &c., setting up a deranged metabolism and disturbing mental equilibrium never stable.

Fifth.—The views of the medical profession as to what constitutes certifiable lunacy suggestive of a widened and widening portal to official registers (senility, slight imbecility, eccentricity, &c.).

FRIDAY, SEPTEMBER 13.

The following Papers were read :—

1. *Shipping Subsidies.*[2] *By* BENEDICT WILLIAM GINSBURG, *M.A., LL.D.*

The importance from a national point of view to a manufacturing and foreign-food-consuming power like Great Britain of the maintenance of her maritime power is self-evident. In that term 'maritime power' must be included the supply of a sufficiency of ships to carry on the nation's commerce. In considering the subject it is necessary first to consider the adequacy or otherwise of the supply of ships whose individual characteristics render them useful as auxiliaries to the navy in time of war, and secondly to regard the conditions under which exist the great bulk of the vessels of the mercantile marine—vessels whose individual characteristics do not matter to the nation, but which nevertheless fulfil the important function of shifting the great bulk of its traffic. On the first point, whilst France, Germany, and Russia

[1] The extreme ratios for the counties is represented by Argyll with 59 per 10,000 of population, and Dumbarton with 19, the percentage difference being 210.

[2] The paper is published *in extenso* in the *Journal of the Royal Statistical Society*, September 1901.

are largely increasing their supply of high-speed ocean steamers, this country shows little progress in this direction; whilst the more recent vessels built for British mail companies are not equal in speed either to those of Germany or even to those formerly built for our own lines. On this account it might well be desirable for military reasons for our Government to consider the advisability of increasing its inducements for building high-speed ships.

The British shipowner works under certain natural and economic conditions of a favourable nature. But he is placed under many statutory disabilities. Yet some of the restrictions under which he labours are not wholly to his disadvantage, since his percentage of loss is lower than that of unregulated marines, and this fact should assist him in placing his insurances at a low premium. The natural tendency of improvements in ship building and marine engineering is towards the gradual extinction of the sailing ship. In our own country this natural movement goes on. In Italy and France an attempt has been made to revive this trade by means of construction and navigation bounties. France has achieved some success in this direction. But it is doubtful how far the shipowner really will benefit from the construction bounty, and no one would be likely to suggest its adoption here.

The notable increase in size and cost of modern steamships seems to tend towards a large concentration of the trade in the hands of big companies and lines.

Competition between the steamship lines of different countries has of recent years developed, whilst the cost of national support to the competitors has very largely increased. Some of the results achieved have been, at least as yet, quite inadequate to the efforts made, whilst a good deal of foreign money is certainly being thrown away in the attempt to foster national trade. Some success is undoubtedly being achieved by the German policy of making the State assist in the unremunerative work of pushing trade in new channels.

This, perhaps, the British Government could not be expected to do. But combined action on a large scale amongst British shipowners might enable them to do that for themselves which foreign shipowners have done for them by their Governments.

2. *Thirty Years' Export Trade, British and Irish Produce,* 1870–99. *By* Barnard Ellinger.

Comparisons of one period of our export trade with another, based on sterling returns of isolated years, are unsatisfactory because the alteration of prices is not taken into consideration, and frequently the years compared are years of different degrees of prosperity

Comparisons of the annual averages of decades have therefore been used in this paper as being more satisfactory than shorter periods, embracing as they do the whole cycle of trade expansion and depression.

If the alteration of price is taken into consideration, the comparison is of course more satisfactory; but the most satisfactory comparison is on a basis of quantity, always making reservations for possible alterations of quality.

It is obviously impossible to satisfactorily compare quantities of such commodities as machinery, chemical products, millinery, &c.; but on comparing the export of eighteen of our chief exported commodities in 1890–99 with 1870–79 (each of which commodities was in some year of the period exported to the value at least 2,000,000*l.*) we find the average of the quantity exported annually during the later decade was 25 per cent. larger than in the earlier.

The sterling value of the eighteen commodities is about 51 per cent. of our total trade, and the remaining 49 per cent. (of which comparisons of quantity cannot be made) show an increase of 37 per cent. in sterling value exported.

The average annual value of our exports of 1890–99 was 19,000,000*l.* greater than in 1870–79.

The average annual value exported per head of the population in 1890–99 was 5·6 per cent. less than in 1870–79; but if it is assumed that the 25 per cent. gain in

quantity on the eighteen commodities (being 51 per cent. of our total export) holds good for the rest of our export, we have an annual average increase of quantity exported per head of population of nearly 9 per cent.

Prices of imports having fallen more in the period under review than prices of exports, the comparatively small total increase in value exported is not of substantial importance if the increase of quantity is satisfactory, as it is this latter factor which denotes the amount of employment found for our people by this branch of trade.

Another objection to relying on comparisons of value is that the returns under this head are probably inexact to a considerable extent both for imports and exports, and although the error may partially correct itself over large quantities, comparisons of the details of the trade are at all events on this ground unsatisfactory.

The error both in imports and exports is probably a growing one, owing to increasing laxity, and also owing to the growth of the export business now done on a C.I.F. basis, which exports would appear to be largely entered for Customs purposes on a C.I.F. valuation instead of an F.O.B. valuation.

The probable extent of the error is a subject which might be investigated by the Chambers of Commerce of this country.

The error on graded qualities of such imports as wheat and cotton is probably small, Customs authorities being able to fairly well control these valuations.

Of the eighteen commodities selected eleven have increased in quantity over 1890–99 as compared with 1870–79: these are woollen and worsted yarns, spirits, copper ingots cakes and bars, cotton goods (bleached and unbleached), cotton goods made of dyed yarns, 'dyed and printed,' cotton yarn, and coal.

In one or two cases, however, notably in yarn, the comparison between 1890–99 and 1880–89 is not so satisfactory.

One commodity, namely, pig and puddled iron, has remained stationary, comparing 1870–79 with 1890–99; and over the same period woollen and worsted tissues, rails, bar angle bolt and rod iron, linen yarn, linen piece goods, beer, and ale show decreases in the average annual quantity exported.

3. *The Theory of Progressive Taxation.* *By* G. Cassel.

Expenses which are made in the general interest of the State, and which are not to the particular advantage of any special group of citizens, must be paid for by taxes according to the 'Principle of Ability,' of which the income-tax might be regarded as the type. But in the parliamentary state, where the interested classes are voting the taxes themselves, this cannot be enforced unless the income-tax is so constructed as to cause every class of taxpayers an *equal sacrifice.*

Equal sacrifice means deduction of such part of the income which is necessary, not only for the physical, but also for the economic, the professional existence of the taxpayer, i.e., *deduction of the 'necessaries of efficiency'* (Marshall), and taxing the remainder of the income at a *constant rate.*

Every progressive scale of taxation can be obtained by the method of granting tax-free deductions to the different incomes, and taxing the remainders at a constant rate. Thus there is no difference in principle between a progressive and a 'degressive' scale. And we need, in the theory of progressive taxation, not discuss any other question than what different deductions shall be allowed to the different incomes.

The subject of the discussion thus fixed, we proceed to apply the Principle of Equal Sacrifice, interpreted as above. For everyone who accepts this principle the whole problem of progressive taxation reduces itself to the question: What are the 'necessaries of efficiency' for each class of the society? But in the limits thus given to the discussion there is room enough for very divergent views, from the conservative one which thinks the real necessities of the labourer to be very small, and which leads to a nearly proportional taxation, to the modern democratic

view, which thinks the labourer's necessities of efficiency to be comparatively very high, and which leads to a strong progression.

As type for the usual scales of progressive taxation the following scheme may serve :—

Incomes from	0s.	till	500s.	pay 0	per cent.
„ „	500s.	„	2,500s.	„ 1	„
„ „	2,500s.	„	8,500s.	„ 2	„
„ „	8,500s.	„	20,500s.	„ 3	„
„	above 20,500s.			4	„

The scale is, from a technical point of view, very crude, involving discontinuities in taxation at every rung of the ladder. We can avoid these if we state that—

The 500 first s.	of every income	pay 0	per cent.
„ 2,000 next s.	„	„ 1	„
„ 6,000 „	„	„ 2	„
„ 12,000 „	„	„ 3	„
All following s.	„	„ 4	„

But this scale can just as well be obtained by the method of deductions; we have only to state that—

The first 500s.	shall have the right to deduce	100	per cent.
„ next 2,000s.	„ „ „	75	„
„ „ 6,000s.	„ „ „	50	„
„ „ 12,000s.	„ „ „	25	„
All following s.	„ „ „	0	„

and that of the remainders a constant rate of 4 per cent. shall be paid. Generally, if in the different groups the tax is to be paid at a rate of $p_1, p_2, p_3 \ldots p_n$ per cent., the same result can be obtained by levying the tax at a constant rate P, not less than any of the p, but granting deductions within the different groups of $\frac{100(P-p_1)}{P}$ per cent., $\frac{100(P-p_2)}{P}$ per cent., and so on.

However, even this method is primitive, and involves too much arbitrariness in fixing the deductions for the different incomes. It is better to let the deduction y increase with the income x as a function of the form

$$y=\frac{\alpha x+\beta}{\gamma x+\delta}.$$

This contains three independent elements, to which comes the constant tax-percentage P, so that the arbitrariness of the progressive scale now is reduced to the choice of four elements. We denote by e the tax-free *minimum of subsistence*, by em the upper limit of the deductions, *i.e.*, of the necessaries of efficiency, and call it the *maximum of subsistence*; the arithmetical medium between these two is the 'medium of subsistence,' and is equal to $e\frac{m+1}{2}$. We denote further by u and v the income and the deduction counted in e as a unity, so that $x=eu$ and $y=ev$. We can then put

$$v=m-(m-1)\frac{n-1}{u+n-2},$$

where n signifies that value of the income u, for which the deduction is equal to the medium of subsistence. Thus we have arrived at a set of formulas where each of the four constants n, m, e, and P has a clear and definite sense.

We can reduce the arbitrariness involved in the construction of a progressive scale still more if we decide once for all that $n=m+1$, *i.e.*, that the medium of

subsistence shall be deduced from an income twice as large. We have then the following formulas to calculate the tax s:

$$v = m - \frac{m(m-1)}{u+m-1};$$

$$x = eu,\ y = ev;$$

$$s = \frac{P}{100}(x-y).$$

The complete fixation of a progressive scale of taxation involves, then, only the choice of three elements, viz.—

The minimum of subsistence e;
the maximum of subsistence em; and
the constant tax-percentage P.

The first and third of these elements must always be decided upon by any income-tax; thus the progressive scale increases the number of arbitrary elements only by one, and this one has a quite definite sense, viz., the upper limit of the necessaries of efficiency of any group of society. In spite of this extreme reduction of the arbitrariness, there remains still room enough for every sensible view of progressive taxation.

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4. *British Agriculture.* *By* Professor Robert Wallace.

The nineteenth century may be divided into six very distinct periods, in which prosperity and adversity to agriculture succeeded each other alternately.

(1) During the first fourteen years great agricultural activity prevailed, owing to the abnormally high prices of corn. All classes associated with land benefited, but the landlords most.

(2) The next twenty years was a time of agricultural depression, although the price of wheat—56*s.* 2*d.* per quarter—in 1836 was more than double—26*s.* 11*d.*—the price in 1900. Bones roughly broken were first used as manure.

(3) The abolition of the Corn Laws in 1846, during the succeeding period of twelve years of prosperity, did not ruin agriculture, as was expected. Peruvian guano, dissolved bones, and dissolved mineral phosphates were first employed as manure, and in 1843 Rothamsted, the greatest experimental station in the world, was opened, to be ultimately endowed by Sir John Lawes.

(4) The fourth short period of temporary but severe depression—1849 to 1852—opened with a sudden drop in the price of wheat. Sir James Caird advocated high farming, which was applauded as usual by people generally, but not followed by the tenants.

(5) Twenty-two years—1853 to 1874—of great agricultural prosperity followed, but economy was not sufficiently studied by either tenants or proprietors. Reliable agricultural returns, dating from 1870, when compared with the corresponding figures of 1900, show a decrease of arable land in the United Kingdom of 2,600,000 acres, but a concurrent increase of 4,600,000 acres of permanent pasture. The rage for steam ploughing and steam digging began, but not till 1898, when Darby introduced a steam digger having a horizontal rotary motion in its digging parts, could mechanical motive-power field cultivation be pronounced financially successful. The success of the string-binding reaper dates from 1870. But it was 1900 before the McCormic Company produced at the Paris Exhibition the Auto-Mower. By the end of the century the oil engine had become the cheapest stationary source of power on the farm. A cycle of good seasons greatly contributed to the measure of prosperity during this period. The average yield of wheat in Britain during the sixties was thirty bushels per acre, and the record yield of 1863 was thirty-nine bushels.

(6) The last long depression which closed the century began about 1875, and, in common with the dislocation of the general trade of the country, was largely

due to currency influences, but also to bad seasons and to foreign competition. Although the active currency influence has passed, by it agriculture has been left in an inferior position as compared with other industries, which were more readily able to adjust themselves to altered currency conditions. Agricultural capital was immensely reduced during the period; but along with the material shrinkage there were many important developments made. Miss Ormerod, between 1877 and 1901, laid the foundation of the subject of economic agricultural entomology. John Garton, of Newton-le-Willows, began in 1880 the system of multiple cross-breeding of plants which has resulted in the production of an infinite number of improved breeds of crop plants; agricultural shows have become more numerous and successful; the cream separator (the Alfa Laval, &c.) has revolutionised the butter trade; the advantages of the system of ensilage have been demonstrated; Thomas's phosphate powder has been employed to encourage clover and improve permanent pastures; the spraying of potatoes with Bordeaux mixture to prevent disease, and of grain crops with 3 per cent. solutions of sulphate of copper to destroy charlock, have both been successful; Hellriegel and Wilforth demonstrated the power of leguminous crops, acting in symbiotic relations with minute organisms living in the wart-like processes of their roots, to fix the free nitrogen of the air; the systems of rotation of crops have also been revolutionised.

Some of the difficulties with which farmers have to contend are the increase of 'aubury' in turnips, the development of a bacterial disease on the swede crop, and the ever-increasing difficulty of the rural exodus, and the scarcity, inefficiency, and dearness of labour, aggravated by an imperfect system of education for children in rural districts.

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5. *Food and Land Tenure.* *By* E. Atkinson.

SATURDAY, SEPTEMBER 14.

The Section did not meet.

MONDAY, SEPTEMBER 16.

The following Papers were read:—

1. *A Business Man on Supply and Demand.* *By* T. S. Cree.

Mr. Goschen, some time ago, expressed regret that there was so little sympathy between business men and economists. This want of sympathy is traceable to a departure by some of our economists from certain views formerly held both by economists and business men, and still generally held by the latter.

A chief principle of all sound economics is the law of supply and demand; the law that supply and demand are always tending to an equality at a certain exact point in price. That law has come to be questioned: John Stuart Mill accepted a correction of it, namely, that the equality was established, not at an exact point in price, but that several different prices might satisfy the law, which, indeed, only brought the price to a kind of tableland where it ceased to be operative, leaving a considerable range of price to be determined by other forces than the operation of the law of supply and demand. Mill held with Thornton that in the labour market, in fighting for a share of that indetermined range of price, the employers possessed so great an advantage by having the initiative in naming the price that nothing but a strong combination of workmen could give the workers even a chance of successfully holding their own against the employers.

It is held in this paper that there is not an inch of ground where the law of supply and demand ceases to operate: it is a law of tendency only, but always to an exact *point*, not to a plane of prices. Mill's correction is not only unnecessary but untrue in fact. The initiative is not an advantage, but a disadvantage in bargaining. Though the law of supply and demand does not fix the terms of every individual bargain exactly, Mr. Mill's remedy, *combination*, greatly increases the area of indeterminateness.

Mr. Alfred Marshall in his 'Economics of Industry' says that an employer is a much larger unit than his men individually; that the workmen are poor and known to have no reserve price; and that therefore union among the men is necessary. These propositions cannot be accepted. Wages are not low because workers are poor and uncombined, but because there are many competing for the job.

Mill and Marshall are wrong in approving of trades unions, and, as Mill puts no limits to the area in which he holds the law to be inoperative, we might suppose that area to be indefinitely large; it might indeed cover almost the whole field, and the law of supply and demand be banished from all discussion of labour questions.

And it is the case that in the economic journals, in the writings of the younger economists and in the constitutions of societies to help the working classes, the idea of there being a law working automatically to a just and satisfactory division is almost, if not quite, absent. Satisfactory division is to be secured through investigations into facts and statistics, and a Government department is suggested to collect these, which one economist speaks of as 'a necessary preliminary to all social progress.'

This view is held to be erroneous. Investigations are not required to give us the proper price of iron or cotton, and there is no good reason why they should be necessary in regard to the wages of labour. Adam Smith had hardly any figures and no facts but such as were patent to everybody.

The want of belief in this equalising law of supply and demand is shown in the ready acceptance of complaints of grievances in particular trades. It is forgotten that all trades have peculiar conditions, but that all tend to an equality of advantage; that the so-called grievance is certainly counterbalanced by some advantage.

No human power could make such investigations as would enable it to make a just distribution of the products of industry. Omniscience and omnipotence would be needed for the task, and the law of supply and demand alone has these qualities. A belief in the beneficent and effective operation of that law in the labour market and the practical repudiation of it by economists and philanthropists is the chief difference between these classes of which Mr. Goschen spoke.

2. *The Decline of Natality in Great Britain.* *By* Edwin Cannan, *M.A., LL.D.*

Between 1876 and 1900 the birth-rate of England and Wales fell from 36 to 29·3 per thousand, but as this rate is calculated on the whole population, it cannot be trusted to show changes in natality. These may be measured roughly by comparing the births of each year with the number of persons born, say, twenty-six years before. The ratio of the births of 1877 to those of 1851 was 144 to 100. Since then the ratio has fallen steadily, till that of 1900 to 1874 was only 108·3 to 100. The ratio between the births and the survivors of the persons born twenty-six years before and still remaining in this country probably fell still more.

The decline of natality does not seem to have been due to a decline of nuptiality, but to the fact that the average number of children resulting from each marriage has diminished. To compare the marriages of each year with the births in that year is misleading, but it is possible to get a useful result by substituting for the marriages of each year a figure in which due weight is given to the marriages of previous years. The following table gives the ratio between the legitimate births of each year and a weighted marriage figure equal to the sum of 2·5 per cent. of

the marriages of that year, 20 per cent. of those of the previous year, 17·5 per cent. of those of the year before that, and so on, with percentages of 15, 12·5, 10, 7·5, 5, 3·75, 2·5, 1·75, 1·25, and 0·75. It will be seen that the ratio or number of children per marriage has fallen from 4·36 in 1881–1884 to 3·74 in 1899, and about 3·63 in 1900:—

Year	Ratio	Year	Ratio	Year	Ratio	Year	Ratio
1851	3·92	1864	4·17	1877	4·30	1890	4·08
1852	4·01	1865	4·14	1878	4·30	1891	4·21
1853	3·87	1866	4·09	1879	4·28	1892	4·05
1854	3·90	1867	4·10	1880	4·34	1893	4·05
1855	3·85	1868	4·16	1881	4·36	1894	3·90
1856	3·97	1869	4·09	1882	4·36	1895	4·01
1857	3·97	1870	4·19	1883	4·35	1896	3·94
1858	3·90	1871	4·19	1884	4·36	1897	3·88
1859	4·10	1872	4·29	1885	4·27	1898	3·80
1860	4·01	1873	4·22	1886	4·32	1899	3·74
1861	4·03	1874	4·26	1887	4·24	1900	3·63
1862	4·15	1875	4·18	1888	4·20		
1863	4·16	1876	4·31	1889	4·21		

The natality of Scotland fell in the same period from the same cause, though the fall was not quite so great.

There is no reason to regret the approach of a time when the population of Great Britain will become stationary, but the cessation of the overflow of population from Great Britain is a serious matter for the British empire, as the natality of the British colonial population is low and diminishing.

3. *The Significance of the Decline in the English Birth-rate.* *By* CHARLES S. DEVAS.

Great increase of population in England shown by the recent census—Character of increase requires examination—Decline of the *natural* rate of increase a result of the decline of the birth-rate—This decline persistent in spite of a higher marriage rate—Likeness to the decline of the birth-rate in France, in North America, and in Australasia—Analogous decline among the Greeks of the second century B.C. described by Polybius—How he accounts for it—Similar decline among the Romans of the classical period—In the six cases of Greece, Rome, France, America, England, and Australasia one common antecedent to the decline of the birth-rate is observable, namely, decay of religious beliefs—Deductive reasoning supports the inductive conclusion of a connection between the two phenomena—How far John Stuart Mill's anticipations on population have been realised in England—Grounds alleged for the slow increase of the French population—Possible special causes of low birth-rates—Striking difference of opinion on whether a low birth-rate is desirable or not—Problems before us.

4. *Correlation of the Marriage-rate and Trade.*[1] *By* R. H. HOOKER, *M.A.*

The application of the theory of correlation to economic phenomena frequently presents many difficulties, and most fallacious deductions may easily be drawn from its careless use, notably with regard to such phenomena as involve the element of time. The usual formula adopted for testing the correspondence of two series of variables is $r = \frac{S(x_1 x_2)}{n\sigma_1\sigma_2}$; in which x_1, x_2 are the deviations of two corresponding observations from the averages of the series, and σ_1, σ_2 are the

[1] Published *in extenso* in the *Journal of the Royal Statistical Society*, Sept. 1901.

standard deviations. But this correlation will clearly only give an indication of the correspondence of the general movements of two curves; whereas the minor movements may be intimately connected, although the general movements may be quite different. It appears possible to slightly modify the usual method of correlation so as to eliminate the general movement in the special case—of very frequent occurrence—where the phenomena exhibit a regular periodic fluctuation, and to correlate the oscillations. All that is necessary for this purpose is to replace the deviations from the average of the whole series in the above formula by the deviations from the *trend*, or curve of instantaneous averages. To determine this *trend*, note the number of observations (p) in a complete phase; the instantaneous average at any particular point is represented by the average of the p observations of which that point is the middle one.

As an illustration the method may be used to determine which of the sets of figures, quoted by the Registrar-General in his annual reports for comparison with the movements of the marriage-rate, is most intimately connected with it, viz., imports, exports, total trade, wheat prices, or amount cleared at the Bankers' Clearing House. The marriage-rate is now lower than formerly, whereas the trade per head has increased: there is thus no correspondence between the general movements, and correlation by the usual method about the average merely confirms this. But the marriage-rate (and four of the other phenomena to be examined) shows fairly regular oscillations with a period of about nine years. Replacing the average of the whole period in these various series by the trend, the 'average' for any one year being the average of the nine years of which it is the middle, we can thus ascertain what correspondence there is between the oscillations of these curves. By correlating the marriage-rate with the trade, &c., of the previous and following years, of half a year earlier, &c., other correlation coefficients are obtained: if these are plotted on a diagram it will easily be seen that there is a point of maximum correlation. This gives a measure of the lag of the marriage-rate behind the trade-curve, the point of maximum correlation indicating the period with which the marriage-rate is most closely connected.

It is thus found that the total trade per head and the amount of clearing are most intimately connected with the marriage-rate, the exports per head is almost as closely, and the imports per head less so, although the correspondence with all four is very close. There is on the other hand no connection between the price of wheat and marriage-rate nowadays. As regards lag, the marriage-rate is now just half a year behind the total trade, three quarters of a year behind the exports, and about one and a quarter year behind the clearing.

It is noticeable that in 1861–75 the marriage-rate was only a quarter of a year behind the total trade and export curves, indicating that it now responds a little more slowly to the general prosperity. It is interesting to observe that this deferment of a quarter of a year (as compared with total trade) corresponds very fairly with the deferment indicated in the marriages by a consideration of the ages at marriage.

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5. *Joint Discussion with Section L on Economics and Commercial Education, opened by* L. L. Price.

In the middle of the nineteenth century the economist exerted a dominant influence over British public opinion, but by the close of the century that influence had become less considerable. The stir now arising on commercial education offers a fresh opportunity for asserting the claim of Economics to a distinct place in the education of the citizen; and two circumstances favour the advance of the claim. On the one hand, the inner history of economic study affords reason for believing that the old controversies, which created such noise, are dying or dead; that the criticism, which has been busy, has been accompanied by a considerable amount of constructive work; and that the popular antithesis between the 'old' and the 'new' schools has lost its meaning, if it is supposed to represent irreconcilable feuds. On the other hand, economic guidance is more urgently required in practical affairs; for many questions coming to the front of popular discussion are

economic in character. The pressure of commercial rivalry, for example, is likely to re-awaken the controversy between free traders and protectionists; and Economics has something of importance to say on this question. The superficial appearance of things may easily mislead, and economists can render unique assistance in disclosing the 'unseen' below the 'seen.' Similarly, with regard to questions classed as 'socialistic,' which are attracting increasing notice, although Economics is not entirely individualistic, and its conclusions may be modified by political considerations, its aid is nevertheless important. Both classes of questions are of special interest for the merchant and the manufacturer. The individualistic spirit prevalent among Americans, who promise to be the most formidable of our commercial competitors, lends emphasis to the danger attaching to a trade union policy which, of unconscious or deliberate intent, may possibly offer real hindrance to the rapid use of new machinery or the speedy introduction of novel business methods. Restrictive legislation, for the same reason, must be scrutinised, although in the early days of the factory system economists erred from shortness of sight, and 'factory reformers' displayed more regard for the permanent welfare of the nation. Economic study is specially calculated to induce the habit of mind needed to discover and expose lurking fallacy.

On this ground a place may be claimed for the abstract reasoning of the text-books in commercial education. Business men deal with the concrete in their ordinary lives, and without some preliminary mental discipline they may fall a prey to unsuspected fallacy. Some training in logic is held by most men to be beneficial, and an acquaintance with economic argument, as expounded in the theoretical reasonings of the text-books, may impart this training in close connection with the phenomena of business-life. Although the business man may act by instinct rather than reason, instinct is often the slow product of large experience: and an ability to see and trace the connection between cause and effect cannot fail to be useful. Without some such mental training the possibility of a 'plurality of causes' and an 'intermixture of effects' may escape recognition; and, as an intellectual discipline, the abstract reasoning of the economists affords a more rigorous and bracing exercise than economic history. Regarded from this stand-point even 'mathematical methods' of study, which induce precision, may find a place in commercial education; but the place cannot be large, as they foster the harmful idea that economic reasoning is too hard for average men. The use of theory as a mental training might be illustrated by many examples; but the theory of money and of banking, which has undergone less change than other theories, and is closely related to the daily life of bankers and financiers, may be taken as a typical instance.

Economic history must fill a very large place in commercial education. It has recently made marked progress. Escaping from arid controversies about method, although the conclusions of one historian may be questioned or rejected by his successors, and much may remain unexplored or uncertain, it is now able to present the broad characteristics and leading events of English commercial and industrial history in orderly sequence for the instruction of the citizen. From the point of view of commercial education too much time may hitherto have been spent on questions of origin—such as the manor—which attract by the opportunity they offer for ingenious hypothesis, but are from their nature difficult to solve, and, by comparison, too little attention may have been bestowed on later but less misty periods. But it is impossible to gain a real knowledge of the causes and conditions of the commercial and industrial success of England without a special study of economic history, as general histories have dealt but scantily with economic matters. The maintenance of that success is, to some extent, dependent on the knowledge and on the investigation of the rise and fall of other nations which have been conspicuous in trade.

Lastly, Statistics, which has also progressed of late, supplies Economics with the means of systematic observation, in default of the more effective mode of experiment open to a physical science like Chemistry. An elementary knowledge of statistical technique and methods is a requirement of the times and a special need of commercial education.

TUESDAY, SEPTEMBER 17.

The following Papers were read:—

1. *A Discussion on Housing was opened by* Professor W. SMART.

2. *The Economic Effect of the Tramways Act*, 1870. *By* E. F. VESEY KNOX, *M.A.*

The Act has now been thirty-one years in operation, and has never been amended. It has been a disastrous legislative experiment. This view is not the result of opposition to municipal trading, nor based on any idea that municipal ownership of tramways is an economic mistake.

I. *History and Effect of the Act.*

The decision in *Reg.* v. *Train* (1862) rendered it necessary to obtain Parliamentary authority to lay down a tramway. The object of the Act was to facilitate tramways by substituting Provisional Order for Bill. It was, however, hedged round with restrictions.

II. *The Vice of the Departmental Method of Legislation.*

The essence of the departmental method is that the inspector who holds the local inquiry (if any) has no authority to decide. The Board of Trade have failed to obtain any respect for decisions in really contested cases. In such cases the practice of promoters is now to go to Parliament direct.

III. *The Want of Compulsory Powers for the Taking of Land.*

English roads are seldom suited for tramways without alteration, yet the Tramway Order may not authorise the taking of land for road widening.

IV. *The Frontagers' Veto.*

Frontagers in narrow places can prevent tramways by a mere mechanical veto. This has led to single lines and other bad tramways.

V. *The Veto of the Local Authorities.*

This veto has sometimes been abused, and has tended to discourage the best schemes and the soundest promoters. It is not, however, likely that an objection by a local authority based on reasonable grounds would ever be overruled.

VI. *The Purchase Clause.*

There were some good reasons for inserting a purchase clause, though nothing of the sort had been applied to railways. and gas and water undertakings have only been purchased under special Acts at a very full price. It is now hopeless to contend that there should be no power of purchase; the really debatable matters are the period and the method of valuation. Mr. Shaw Lefevre anticipated that promoters would not mind the purchase clause because there was no limitation of profits. What they did was to try to take their profit through inflating the capital, and clear out. Hence abortive schemes and disappointed investors. The comparison between the price at which railway and tramway capital can be raised is not less instructive than that between private and municipal credit for tramway purposes. The best class of investors have been discouraged by the Tramways

Act, and the cost of capital for tramway enterprise has consequently been increased.

The great discovery of the application of electricity to tramways came just when the purchase periods in England were running out. There was consequently a long delay in adopting the new invention, and though England ought, but for Parliament, to have led the world, as it did in railway construction, it has been kept behind other countries, and has suffered social, economic, and industrial loss. There is no other country which had so great a need for electric tramways as England.

The corporations have been slow to try experiments owing to their careful trusteeship of the ratepayers' money.

The method of valuation is more important than the period of purchase. If goodwill is not to be paid for there is no adequate motive for developing a business. The corporations have actually lost on balance, for while Tramway Act price is less than enough for a good tramway it is too much for a bad tramway. It pays the company better, when the purchase period is approaching, to retain an obsolete equipment, which ought to be scrapped, so as to make the corporation buy it.

Practically no tramways are now made by companies on Tramways Act terms without modification; but the retention of the Act on the statute book still does a great deal of injury to tramway enterprise.

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3. *Notes on Glasgow Wages in the Nineteenth Century.* *By* A. L. Bowley, *M.A.*

The statistics available for an estimate of the changes in the rates of average wages are very numerous, but it is only in a few cases that a reliable calculation extending over half a century can be made.

The following table shows in rough form average money wages (assuming no change in regularity of employment and averaging over ten or twenty years) in various industries, expressed in each case as percentages of their level in the decade 1890–1900:—

	1790	1810–1830	1830–1850	1850–1860	1860–1870	1870–1880	1880–1890	1890–1900	1900
Building (Glasgow)	35	50	50	65	70	86	83	100	110
Coal-hewer (Lanarkshire)	50	70	60	61	62	93	77	100	135
Engineering (Glasgow) (Artisans on time-wages)	—	—	—	67	72	83	90	100	110
Printers—Compositors (Time-wages)	—	—	73	73	75	83	94	100	110
A.B. Seamen (Money-wages)	—	—	1850 70	90	90	100	90	100	110
Rough general average	—	60	55	65	70	85	80	100	115

The general average would probably be affected if allowance were made for such changes in the construction of the working-class population as the growth of the class of partially skilled workers.

No attempt has been made to include any estimate for the changes in the purchasing power of money.

4. *The Poor Law and the Economic Order.* *By* T. MACKAY.

Early legislation concerning the poor was for their regulation, not for their relief. It was based on an assumed adscription of the population to the soil. The obligation of the community to relieve was of later origin. On this territorial basis was founded our system of poor relief as established by Elizabeth.

The legislature regarded the population as stationary, but it was not till some fifty years afterwards that the mobility characteristic of an industrial population came into conflict with this assumption.

For remedy the 14 Charles II., c. 12 (1662), attempted to define settlement and facilitated the forcible removal of migrant labourers to their place of settlement. The tyranny of this has often been condemned, and from the first many methods of evasion were adopted. The complete immobility of the population, however, was due, not to this enactment, but to the guarantee of maintenance held out to everyone who clung resolutely to his parish and to his decaying industry. It was this system of imprisonment in some 15,000 parishes that gave rise to the appearance of over-population. Labour was rendered immobile, not only in place, but in character and habit.

The business of the new poor law in 1834 was to relax these bonds and allow the absorption of the population into the economic order. It was in large measure successful, and subsequent experiments in the way of restriction have sought to carry the reform further. The justification of a restrictive policy is that pauperism is a retention of a part of our population in a condition of primitive poverty much longer than the economic necessity of the situation warrants. This archaic survival is to be contrasted with the economic order, which offers the true policy of emancipation.

The hand-to-mouth life is now more amply endowed than it has ever been; a consideration which answers the argument that, in view of the improved conditions of working-class life, a relaxation of poor-law tests is desirable. Improved opportunities for independence too often merely go to make the proletariate life, for the time being, more profuse and irresponsible. The difficulty is to induce a certain type to submit, in even the slightest degree, to the discipline of the economic order and to renounce its much more natural, primitive, hand-to-mouth instincts.

Maine's generalisation that progress is from status to contract is based on historical fact; but as regards the future it may not be the last word. It is submitted, however, that, even if we welcome a tendency to revert in certain directions to civic and municipal status, the status of parochial pauperism is a condition from which we should endeavour to emancipate our poorer population.

5. *British Colonial Policy in its Economic Aspect.* *By* ARCHIBALD B. CLARK, *M.A.*

The timely and substantial assistance rendered to Great Britain by the Colonies in the South African War has awakened a fresh interest in the question whether a more formal recognition and exact definition should not be given to the rights and responsibilities of the Colonies in connection with the government and defence of the Empire. The problem, like nearly every practical problem, is not exhausted by consideration of its purely economic aspects. But the policy of 'tightening the ties' is, at present, advocated mainly on economic grounds; and it is sought to attain the end in view by the manipulation of economic factors.

As regards defence, under modern conditions a huge and growing expenditure on the Army and Navy is inevitable; and it is argued that the Colonies, who equally with Great Britain gain from the resulting security, may fairly be asked to contribute towards the expense. But (*a*) by way of compensation our weight in the councils of the nations is vastly greater by reason of the possession of our Colonial Empire. (*b*) Recent experience suggests that the interests of Imperial Defence may be better served by the spontaneous action of the Colonies than by a formal and binding contract.

It is thought that we might find material compensation, and at the same time meet the hostile tariffs of foreign countries and increase the strength of the Empire, by entering into a Customs Union with our Colonies on the basis of free trade within the Union and protection against the foreigner. Or, failing that, we might adopt a system of bounties on trade with the Colonies. But (*a*) we rely on the foreigner for food and raw materials: and of the total external trade (import and export) of the United Kingdom, roughly 75 per cent. is, and has been for half-a-century, a trade with foreign countries. (*b*) The diversity of interests, too, among the Colonies themselves renders it hopeless to expect that any scheme could be formulated which would fail to create discord. (*c*) Any such scheme—whether of differential duties or bounties—would involve a serious departure from our free-trade policy the great virtue of which is its practical simplicity.

Like that free-trade policy, the existing connection between Great Britain and her Colonies may be imperfect in theory, but, like it, it has proved workable in practice. Under the one we have enjoyed half-a-century of unrivalled prosperity; and, as the outcome of the working of the other for a similar period, we have amongst the Colonies a sense of unity and an intensity of loyalty to the mother country unparalleled in history. This, too, has been most unqualified where the hand of 'Downing Street' has been least conspicuous. The policy of 'tightening the ties' is really retrograde and unhistorical. It represents the extreme of reaction from the view which prevailed generally from about 1840 to 1880—that the independence of the Colonies would be the natural outcome of the concession of self-government. It involves a return to that system of monopoly and interference by the central government which in the eighteenth century lost us the American Colonies. In our colonial policy the most pressing need at present is concentration and economy, based on recognition of the truth that trade follows the flag in no other sense than that it follows the establishment of peace, security, and good government.

6. *The Present Position of Woman as a Worker.* *By* Miss M. H. Irwin.

Owing to the rapidly increasing number of women who are year by year entering both the professional and the industrial labour market, the nature and conditions of women's employment form a subject of first importance to the economic student, not only in relation to the women themselves, but also in respect to their men fellow-workers, and the general development of our national industries. Many industrial complications have arisen, and threaten still to arise, from the presence and the extended application of women's labour.

There is a want of adequate and authoritative information regarding women's work. The subject has suffered in the past from being regarded as a matter for philanthropic sentiment rather than economic research. A change of attitude is being brought about through various causes.

The need for systematic inquiry and exact knowledge as providing a basis for both philanthropic effort and legislative reform. Legislative action is specially desirable for the regulation of the conditions of women's work, owing to the difficulty of forming any organisation among them sufficiently strong to protect them from possible evils in the way of excessive hours and other unhealthy conditions of work.

Results of investigations undertaken by the Scottish Council for Women's Trades and other bodies into various employments followed by women in which there was either no legislative restrictions, or these were defective. Laundries, shops. Investigations into home work. The economic results of home work. The sanitary side of the question. Proposed regulations. The dressmaking trade. The tailoring trade. A complex and highly graded industry of special value as a subject for economic investigations.

Among the suggestive points offered for study by the tailoring trade are the competition between the men and women workers. The results of the introduction of the cheap and unprotected labour of women, systems of wages rating, displacement of the skilled hand labour of men by the machine-tended and comparatively

unskilled labour of women. The rise of the clothing factory and spread of the division of labour system, the operation of factory legislation, and the Public Health Acts. The difference between the rates paid to the two sexes for work of the same nature and efficiency. The absence of a standard and uniform rate for women's work.

Causes which may account for the lower wages-rates of women. Attitude of the men's Union towards the women workers. The nature and significance of women's competition. The extension of mechanical aids favouring the increased application of women's labour. The typographical trade. The new printing machines and the scarcity of boy labour furthering the employment of women. The textile trades of Scotland. These have become practically women's industries since the introduction of the power-loom. Bookbinding. The non-employment of women in many departments of this trade is due to artificial restrictions, such as custom, and the lines of demarcation laid down by the men's Union. So far as an investigation into the printing, bookbinding and kindred trades which is now in progress has gone, it would appear that while machinery has displaced hand labour in certain departments, owing to the largely increased output, there has been an increase in the total number of workers employed all over the factories coming under observation.

In view of possible future industrial changes, in which women's labour is likely to be a very important factor, there is urgent need for systematic investigations of the nature and conditions of women's labour.

WEDNESDAY, SEPTEMBER 18.

The following Papers and Report were read:—

1. *The Real Incidence of Local Rates.* *By* CAMERON CORBETT, *M.P.*

The incidence of local rates is fundamentally influenced by the question as to whether the area affected by them is fully built up or is affected by a practical chance of additional accommodation being provided within it. If it be fully built up, then the rate falls on the owner except in so far as the cause of the rates is calculated to affect the rents beneficially; that is to say, the burden of wasteful administration would fall upon him. In the cases where a higher rate affects an area where building can be influenced by it, the burden falls on the tenant in the same way as the burden falls on the consumer of a manufactured article, production being checked thereby.

The proposal, after taxing building and land together, to put a special second burden on land values would raise the price of houses to buyers, and consequently the rent to tenants. The reduction of four years' purchase in the selling price of ground rents which has taken place during recent years has amounted in many instances to more than the whole cost of the land, and has therefore affected the production of houses as unfavourably for the occupiers in these cases as if the cost of the land had been doubled. It is quite evident that land values being exposed to a special rate would affect the buyers and tenants of houses very severely, for the builders would require to get as much additional inducement from the buyer of the house as would counterbalance the lessened amount they would receive from ground-rent buyers.

2. *Recent Results of Farm Labour Colonies.* *By* HAROLD E. MOORE, *F.S.I.*

At the Liverpool Meeting in 1895 a paper was read on 'Farm Labour Colonies and Poor Law Guardians.' It was then pointed out that farm labour colonies might be considered to be of two distinct classes. One of these would be colonies for the reception of well-conducted men of the working classes temporarily out of employment; and the other class would be colonies for the

reception of men who would otherwise be in the casual wards, inmates of workhouses, or dependent partially on private charity. It was suggested that the establishment of colonies of the first class was difficult; but the further extension of the second named was recommended as being both desirable and practicable.

During the last six years there has been extension in the work of the last named, and so far with satisfactory results. Colonies under the control of voluntary committees, but subsidised by grants from Boards of Guardians, are at work: (a) At Hadleigh in Essex, under the control of the Salvation Army; (b) at Dorking in Surrey, under the control of the Church Army, in succession to a smaller one carried on by that organisation near Ilford in Essex; and (c) at Lingfield in Surrey, and another near Kendal in Westmoreland, under the control of the Christian Union for Social Service. The financial and other results of each of these efforts from their economic aspect is separately considered.

There are also colonies in operation not subsidised by Poor Law funds, the most important being the one under the control of the Scotch Colony Association, near Dumfries. There is also a colony for women only, founded by the efforts of Lady Henry Somerset, near Reigate in Surrey, as well as some smaller private attempts at providing work on the land as a means of relief; while Guardians at Sheffield and elsewhere are working land.

The results show that colonies for the second class (a) have reduced the cost of maintenance of those there received as compared with the expense of their maintenance in other ways; and (b) have been beneficial as a reformatory influence when the work has been under the control of Christian voluntary committees, restoring some to independent life who would otherwise have remained in a permanent dependent position.

3. *Feebleness of Mind, Pauperism, and Crime.* *By* Miss MARY DENDY.

The special point to be proved is this: we are to-day suffering from an evil which will, if unchecked, bring ruin upon our nation, and that before very long. A chain is no stronger than its weakest link, and the weakest link in the chain of our social life is the mass of mentally feeble persons who live amongst us, unguarded and unguided, suffering and helpless, a danger to themselves and to Society, and perpetually propagating their species. The time has come when this evil must be dealt with, very tenderly, very kindly, so far as individuals are concerned, but very plainly, very scientifically, so far as Society at large is concerned. As years ago our nation realised that we had no right to populate a new country with criminals and ceased to send its convicts abroad, so now we should realise that we have no right to provide for our own future a feeble, helpless, half-witted population. That this is what we are doing at present there is no doubt; the main cause of feebleness of mind is heredity.

The time is come when we should ask for scientific morality, should question what is morality worth which is *not* scientific, and should demand that the transmission to the future of a terrible evil shall be stopped—an evil which brings all other evils in its train. It is not only that our weaker brethren themselves become criminals; they afford the opportunity for crime in those who are not weak but only bad. It is probable that two-thirds of the crimes of our nation might be prevented in the course of two generations by a scientific method of dealing with the feeble-minded. And we must remember that it is futile to talk of weak-minded criminals as sinners. Sin there must be, where so much crime and misery are; but the sin lies where the responsibility lies, and that is with the sane and not with the insane.

The one defect most generally common to weak-minded persons is great weakness of will-power.

There is a whole class whose feebleness consists in a total lack of the moral sense. It was of these that Huxley wrote: 'As there are men born physically cripples and intellectually idiots, so there are some who are morally cripples and idiots, and can be kept straight not even by punishment. For these people there is nothing but shutting up or extirpation.'

Many persons who are, when left to their unassisted efforts, quite helpless can earn a living, or partly earn a living, when under constant supervision. The lacking will-power can be imposed from without. The late Sir Douglas Galton said that the feeble-minded man could never be worth three-fourths of a man. That three-fourths, at least, could generally be arrived at in proper conditions. His weakness of will makes him obedient to any suggestion; he can be trained to make use of all the faculties he possesses, and those faculties, though they cannot be made normal, can be greatly strengthened. Thus in good hands he may become nearly self-supporting, while in bad hands he is self-destroying.

However, the Commissioners in Lunacy have given us a good working definition of the feeble-minded. They speak of 'persons who are known as the feeble-minded. They are not the subjects of such a degree of mental unsoundness as in the opinion of the medical officers renders them certificable in the eye of the law, and they are, therefore, unable to be detained against their will, although they are not sufficiently of sound mind to be able to take care of themselves.'

Briefly what happens to a feeble-minded boy (and there are three boys of this type to every two girls) is this: He leaves school quite unable to take care of himself; very often the one wholesome influence of his life ceases with his school-days, his parents being very little stronger in mind than himself. Their one idea is to make him earn money for them. He knows no skilled work and cannot keep a situation if he gets one. He comes upon the streets, sells matches, shoe-laces, papers, and generally ends by turning up in gaol. By this time he has become used to a vagrant life, and as he can only move along the path of the least resistance, and as it is made so much easier for him to go wrong than to go right, he goes wrong persistently, and becomes a confirmed criminal. So he grows up through a pitiful and degraded youth to a pitiful and degraded manhood and dies, leaving behind him offspring to carry on the horrible tradition. With the girls the evil, though not more real, is more obvious, and for this reason more attempts have been made to help them than their brothers. Of course, in accidental cases, where the parents are respectable, they do their best for their weakly children, and try to keep them at home or with kindly employers. But if they are of the wage-earning class they ultimately, in nearly every case—their natural protectors dying—come upon the rates. The main cause of this terrible evil is, undoubtedly, heredity. The child of a feeble-minded parent is likely to be one degree at least worse than that parent. Dr. Caldicott, of Earlswood, says: 'In our statistics the one cause which stands prominently forward is *Heredity*, and the more accurately we are able to penetrate the family history of our cases the more we are forced to the conclusion that a very definite "neurotic" taint is found in the direct and immediate progenitors. For my own part I believe this to be as high as 70 to 75 per cent.' Dr. Müller, of Augsburg, also states that 70 per cent. of weak-minded persons are accounted for by heredity.

The English law has at length recognised the existence of these people as a class, apart both from the sane and the certificated insane.

It now permits educational authorities to make provision for them, but only up to the age of sixteen. As if those who are mentally unsound at sixteen would be mentally sound at seventeen!

In 1898 there were 100,322 children on the books of the public elementary schools of Manchester. Of these 44,463 were in the Board school. I now proceeded to make an inspection of all these Board School children, and I saw at their work, all who were in actual attendance, 39,000. When I saw a child who seemed to me abnormal, I made a special examination of it, speaking also to normal children so as to avoid singling out any one for remark. With the aid of an attendance officer, I took down all particulars concerning the child. In this way I made notes on 525 children. This report would, of course, not in itself have been reliable evidence. But when it was complete we were so fortunate as to secure the help of Dr. Ashby, our great children's doctor, the head physician of our children's hospital, a man whose opinion is acknowledged to be the best possible. He most kindly consented to see all my cases. He examined every child carefully and gave a written opinion on each. He summarised the

result thus: 'Out of 500 examined, 214 were dull and backward (it being understood that the backwardness arose from the child's condition, not from home conditions), 276 were mentally feeble, 4 were deaf-mutes, and 6 did not appear to be sufficiently behindhand to come under either of these terms.'

Adding the proportion for the voluntary schools in Manchester, we have about 1,000 children who are mentally unsound in the day-schools at one time. Since then I have worked in a similar manner through all the voluntary schools in a large non-School Board area with similar results. Wherever an attempt has been made to obtain correct statistics, these figures are confirmed. To conclude. Prudence, economy, and humanity demand that we shall deal with this question rationally. It is possible at an early age to detect the unsound brain; scientific morality demands that we shall take care that our weak-minded children are always protected, so as to render them harmless to themselves and Society.

I shall ask you to dwell on these facts:—

Our workhouses and lunatic asylums cannot provide for our derelict population.

Lunacy and imbecility and pauperism are largely on the increase.

Two per cent. at least of our school-going population are in some degree weak-minded—some more, some less. Feebleness of mind is hereditary, with an increasing intensity.

Almost all feeble-minded persons are at large during the most critical period of their lives, and most become parents.

It would be easy to detain such persons if the detention were commenced in early youth, and they could be kept happy, harmless, and partially self-supporting for their whole lives. They would then be no danger to Society, and they would be far smaller expense than they are.

4. *Report on the Economic Effect of Legislation regulating Women's Labour.* —See Reports, p. 399.

Section G.—ENGINEERING.

President of the Section—Colonel R. E. Crompton, M.Inst.C.E

THURSDAY, SEPTEMBER 12.

The President delivered the following Address:—

At this the first meeting of the British Association of the new century I wish to lay before you some of the interesting problems presented by recent developments in means of locomotion on land which demand the best thoughts, not only of our engineers, but of everyone interested in the improvement in means of travelling and in the more rapid transit of goods.

During the seventy years which have passed since the introduction of railways in almost every country passenger and goods traffic has developed itself to such an extent that almost everyone is interested in these questions; and of late years our attention has not been confined to railways only, but, owing to the invention of the cycle and motor-car, has also been directed to travel on our road-ways, which during the first fifty years of the railway era had somewhat fallen into disuse. I am not able, being limited to the length of this address, to deal with many of the interesting questions affecting our long-distance railways other than by referring to the probable early introduction of railways of a new type intended to attain a speed of 120 miles per hour and worked by electrical power. The railway race to Scotland of a few years back attracted the attention of the managers of American and Continental railways to railway speed questions, and we have seen during the last few years so great improvement in the speed of the trains and the comfort of the passengers in these countries that it appears that England has already been beaten in the matter of extreme railway speed, although it is probable that our railways still provide a larger number of rapid trains than either the American, German, or French do. But whether it be in England or in the countries I have mentioned, it appears that after all the speed limit of railways of the present system of construction is reached at about sixty-five or seventy miles per hour. Higher speed on level runs has undoubtedly been recorded, but it is not probable that anything greatly in excess of seventy miles per hour will be reached until our railway managers initiate an entirely new system of construction. The high-speed service that is now in contemplation, not only in England but in America and Germany, intends to attain speeds of over one hundred miles per hour by providing electrical means of haulage sufficient to propel light trains consisting of one, or, at the most, a few cars; and in order to render this service successful to run these light trains at short intervals of time, so in effecting this high speed the railways will give a service which more nearly resembles the tramway service than our present system of heavy express trains at infrequent intervals. This high-speed service of light trains at frequent intervals is well suited to electrical haulage, as it works generating machinery situated at fixed points to the best advantage and enables the best return to be obtained from the necessarily heavy capital cost

of copper in the conductors which transmit the energy along the length of the line, as it is evident that if the speed be sufficient to ensure that each section of the line only carries one running train, the costs of the conductors will be in proportion to the weight of that train.

Great advantages have already been made in adapting electrical traction to long lengths of railways. The work already done by Brown Boveri, of Baden, in Switzerland, at first on the mountain railways and afterwards on the Burghdorf-Thun full-gauge line, the experimental work of Ganz & Co., of Buda-Pesth, and of Siemens & Halske at Charlottenburg, have already shown that the power problems are nearly all of them solved, so that we may feel confident that electrical engineers will very shortly surmount any power difficulties that still remain. But this high-speed railways problem at present presents certain unknown factors which can only be satisfactorily determined by the actual testing and working the lines when carrying passengers. I refer to those which deal with the increased oscillation, vibration, and noise to be expected from the extreme speeds. These matters must be met so as to give sufficient comfort and protection to the passengers, for if passengers are rendered uncomfortable by the extreme speed the service can never become popular, and on this last question depends the most important question of all, viz., the extent to which the travelling public are likely to make use of a high-speed railway service. In attempting to forecast this matter, although we meet many business men who think it would be an undoubted advantage if the journeys between important business centres occupied half the time they do at present, in the United Kingdom there are only a few journeys of sufficient length to make saving of time of great importance, but the case is far different in America and on the Continent, where the business centres are much further apart than they are here. I, as an English engineer, foresee that this topographical question will cause our English engineers to be at a disadvantage as compared with American and Continental ones, for it appears likely that the number and mileage of high-speed railways is likely to be far greater in America and on the Continent than in the United Kingdom. Before I entirely leave the subject of very high-speed railways, a rather curious speculation presents itself to us: this is whether the need for rapid communication between town and town may not eventually be supplied by high-speed motor-cars on roads specially prepared for them. Mr. Wells in his interesting forecast in the 'Fortnightly Review' seems to think that the time is not far distant when all passenger traffic will be carried on special roads on motor-cars. That the advantages of carrying your family and loading up your belongings at your own door, in your own or a hired car, and transporting them without any change or handling of your baggage right up to the point where your journey ends, will be so great that even for comparative long journeys travellers will prefer it to the railway, and that our railways will eventually be relegated to carrying minerals and heavy goods. But, without going so far as Mr. Wells, it does seem probable that if only a few passengers require to travel between two business centres such as Manchester and Liverpool, and to occupy only half the time from door to door at present taken by the railway and the two terminal cab rides, it might be better to provide one of Mr. Wells' improved roads on which private owners could run their own cars, paying toll for the road, and on which a public service of cars would provide for those who did not own cars themselves.

I now propose to deal at somewhat greater length with what I think is a most important problem in locomotion, viz., that caused by the congestion of street traffic in our towns and by the undoubted difficulties which exist in carrying our workers to and from their homes in the country to their places of employment in our towns. A large proportion of the workers who during the latter half of the last century lived and worked in the country are now working in towns, although some of them still live outside in order to obtain the advantages of lower rents and of a healthier life for their families, and this last class is likely to largely increase. Those who have been responsible for the enlarging and improvements of our towns have done so much to make town life preferable to country life that the country is gradually being depopulated. The results we see in the increasing difficulties which the town authorities find in dealing with the water and sewerage

questions, and in the increasing mass of vehicular street traffic, which makes some of our cities veritable pandemoniums. Luckily it seems that we are likely through the skill and energy of our engineers to meet these difficulties in more than one way. The cycle, which commenced as an amusement and went on as a fashionable craze, has now settled down into being the poor man's horse. The number of our working population that use the cycle for going to and from their work is already very large and is steadily increasing, and their use of the roads must be considered. Then came the motor-car, developed in France to such an amazing extent, and which seems now likely to be developed to an equal extent in this country. After many years of objecting to the use of the overhead trolley system, our town authorities seem now to have determined that the only way of relieving street traffic is by an enormous development of electrical tramways, and on all sides we find the large towns rivalling one another in the extent of the tramway systems which they have either acquired or are laying down for themselves. It seems opportune now to point out that a great deal of mischief may accrue by this indiscriminate use of tramways, and for those who are considering these matters I bring forward a few facts which are worthy of notice. Of course, in new countries, or in new towns in old countries, where the roads are rough and bad, anything in the nature of a tramway using rails is an improvement on a roadway; but when we are dealing with cities which already possess well laid out and well paved streets on which all kinds of wheel traffic can be carried on with a minimum of rolling resistance, it seems wrong from an engineering point of view to break up the surface of these streets for the purpose of laying tramways, and for the following important reasons: Traffic carried on a roadway by vehicles, whether horse-drawn or by cycle or motor-car, differs from traffic carried on rails chiefly in that the former vehicles possess an important power, viz., that of *overtaking*, which is not possessed by the latter, that is to say that vehicles on the plain road surface can overtake a stopping or a slower vehicle going in the same direction without interfering with other vehicles, whereas on rails the vehicles going one way must always remain in the same relation to one another, so that the speed of vehicles on rails must always be regulated by that of other vehicles going in the same direction. Street tramways, for instance, must stop to set down and take up passengers: this limits the speed average and the number of vehicles per mile of track, for if there be not sufficient intervals between the vehicles they would have to stop and start nearly simultaneously. Thus the carrying capacity of the best modern electrical tramway is limited by this want of overtaking power. I have made careful inquiry from those who have great experience in tramways not only in this country but in America and on the Continent, and I find that it is generally admitted that the maximum carrying capacity of an electrical tramway in one direction is 4,000 passengers per hour carried past any given point. I find that a full-gauge suburban or metropolitan railway crowded to its fullest extent cannot carry more than 12,000 passengers per hour. Now most of us have often seen large crowds taken away from a point of attraction by omnibuses and horse-drawn vehicles, and have noticed that the crowded omnibuses almost touch one another and yet can go at a fair rate of speed. In this case at eight miles per hour speed 14,000 passengers can be carried from a given point per hour.

Up to the present a public motor-car service has not yet been installed of any magnitude to enable us to compare the carrying capacity of motor-cars with that of horse-drawn omnibuses, but owing to the reduced length of motor-cars compared with that of omnibuses, and on account of their greater speed and greater control, motor-cars can now be built to deal with great crowds at an even higher rate per hour than that noted above. It appears certain, therefore, that although the provision of electrical tramways is undoubtedly an economical means of carrying passengers, yet that these tramways cannot be laid in existing thoroughfares without considerably reducing the total road carrying capacity at times of heavy pressure of traffic, and as it appears likely that either for the daily transport of the workers to and from their homes to places of employment, or for taking great crowds out into the country for pleasure purposes, a motor-car service carried out

on well-made roads will compete favourably with, and in many ways may be preferable to, tramway service.

It must be remembered that the laying of tram rails not only blocks ordinary traffic, but in our most crowded streets it introduces dangers to all wheeled vehicles not on rails, motor-cars, and cyclists by the skidding of the wheels when they cross the line of rails, and these dangers are daily causing, and are still likely to cause, very serious accidents.

The increased road and street traffic and the development of new means of road locomotion have made imperative some modification of our existing system of roadway administration. Cycles, motor-cars, electrical tramcars, have been invented and put on roads which are maintained and worked exactly as they were seventy years ago at the commencement of the railway era, when the population of the United Kingdom was half its present figure, and that of the large towns one-tenth of the present figure. During the 150 years previous to the railway era the ancient tracks were gradually improved into tolerably efficient roads for coach and wagon traffic, but after the introduction of railways there was a complete cessation of improvement, as for fifty years after the railways started the old roads were equal to the farmers' and local traffic which the railways left for them; but for the last twenty years the roads near to the great towns have been inadequate, and now that the cyclist and motor-carist travel over the whole of the roads of the country the neglect of our ancient roadway system is very apparent.

Although the urban populations have so greatly increased, the old coaching roads are still the only ones that exist: no main roads parallel to the old ones or alternative to them have ever been made. Towns which are now joined by railways grew out of small rows of houses built facing the main road; in fact in many cases the road made the town. During the early part of the railway era, when the roads were so little used from coaching falling into disuse, encroachments on the roadway took place in and near the towns, such roads being now actually narrower and less suitable for traffic than in the coaching days: so that these towns which owe their existence to these roadways now put every impediment and hindrance to their use by the travelling public. What is needed is that towns situated on our main through roads should provide alternative routes, so that through travellers could, if they desired, avoid the crowded streets of the town. One method of providing such relief roads would be by by-laws providing that all building estates should set aside land for main roads. The building estates which are developed around our great towns never provide a road which can be used as a main line of thoroughfare, although by their very act of building additional houses they cause additional congestion to the main roads. They lay out their roads to obtain quiet for those who live on the estate, and take every possible means to prevent their estate roads from taking a share of the main thoroughfare traffic.

Parliament must take in hand an improved administration of our highways by a comprehensive scheme. Far too many ancient main lines of thoroughfare, already too narrow for the traffic which is on them, are being blocked by having tramways laid on them; these cause the development of building estates, which throw additional traffic on to these thoroughfares. Apart from the roads themselves, the complicated conditions of street and road traffic demand careful regulation. Street traffic should be carried as far as possible by lines of vehicles driven as nearly parallel to one another as possible. The rule of the road, as it is called, and which is embodied in an Act of Parliament, 5 and 6 of William IV., which is commonly called the Highways Act, says that every vehicle is to keep as close as possible to the left, or near side of the road, except when overtaking another vehicle going in the same direction, and then it is to keep to the off side of the overtaken vehicle as closely as possible. As a matter of fact, everybody knows that this rule is habitually neglected by drivers who, whenever they get a chance, drive down the centre of the road, so that others who overtake them dare not do so on the wrong or near side, but must pass out far to the off side of the road, and consequently interfere with the traffic coming in the opposite direction. This neglect of the rule of the road causes a great waste of space immediately behind every vehicle, and is one of the chief causes

of the limited carrying capacity of the streets in cities where the police do not attend to this important matter. It can be remedied by the existing police regulations being adhered to and insisted on by fixed-point constables, or by constables moving about on motor-cars or bicycles. Slow moving and frequently stopping vehicles are another cause of congested traffic. A great deal might be done by arranging that during certain hours much of the slower moving traffic is shunted into alternative routes, so as to be kept by itself. An increase in the speed of the street traffic is desirable; for the faster the vehicles travel the less the street is occupied by them. Motor-cars can safely travel at sixteen miles an hour, and, therefore, need only take half the time and occupy only half the street surface that an omnibus does when travelling at eight miles per hour. Such high speeds as these, which are desirable and perfectly safe for motor-cars, cannot, however, be obtained unless some regulations are made as to the use of the roadways by foot passengers. There is no rule of the road for foot passengers—they pass one another on the footpath, or vehicles in the roadway, just as they please. No driver of a vehicle in the road who sees a foot passenger stepping into the roadway can ever tell with certainty what his movements will be. It will be no hardship to foot passengers to insist on their movements being regulated.

Much has been recently said and written on the subject of motor-cars and motor-wagons. It is generally admitted that there will be considerable scope for engineering skill and capital in their improvement and construction. It is by no means an easy problem to put into the hands of the public such a complicated piece of mechanism as a self-propelled carriage which has in most cases to be managed and driven by men who have had no special mechanical training. Motor-cars to be universally successful must be made so as to reduce to a minimum the liability to break down; repairs must be limited to the replacement of worn or damaged parts by other parts, which must be supplied by the manufacturers so that they can be readily put in by the unskilled users. That this can be done is shown by the success and universal use of typewriters, sewing machines, and bicycles: all of these are really complicated pieces of mechanism, but which are now in such general use and in everyone's hands. In these cases, however, the organised manufacture of machines with thoroughly interchangeable parts, or components as it is the fashion to call them, has only been developed after the type of machine had settled down, and this up to the present cannot be said of the motor-car or motor-wagon. Up to the present the development of these cars has gone on on several lines. The development in France, which so far has led the world, has been principally in the direction of the use of light motors driven by petrol spirit. Again to France we owe the flash boiler of Serpollet, which assists the use of steam engines for this purpose.

At first sight steam, with the complications of boiler, engine, and condenser, does not appear likely to compete favourably with the simpler spirit motor, but for heavier vehicles, where steady heavy pulling power is of importance, up to the present no internal combustion motor has competed with it. The Americans, with their usual skill and power of rapidly organising a new manufacture, have already turned out a very large number of steam-driven motor-cars, which are so largely in use in unskilled hands that it shows that they have already solved the problem to some extent.

The directions in which the two classes of motors require further development are, for the internal combustion motors, the satisfactory and inodorous use of the heavier oils, and in this perhaps Herr Diesel may help us with his wonderfully economical motor improvements in the clutch mechanism, for with all internal combustion engines up to the present it has been found impossible to start the motor when coupled to the driving-wheels of the car; and in the case of the steam motor the simplification of the boiler, the boiler feed mechanism, the inodorous and noiseless burning of heavy oils as fuel, improved condensers, methods of lubricating the pistons and valves so as to avoid oil passing back to the boiler with the condensed water, and the rendering of all processes of boiler feed and fuel feed mechanism completely automatic so as not to require the attention of the driver. On points common to both classes, although much has been done, further

improvement is required in the methods of transmitting the power from the motor to the driving-wheels. In the case of the steam cars, where this has been done by single reduction, using chain, pinion, and sprockets, very efficient and noiseless transmission has already been obtained, but up to the present in most of the internal combustion engines where more than two cylinders have to be employed, it has been found necessary to arrange the crank shaft of the motor at right angles to the axle of the driving-wheels, so that part of the transmission having to be through bevel gear, this part has up to the present always been noisy. In the providing of noiseless and efficient chain driving, the manufacturer of cars has gained greatly by the high degree of perfection to which these chains had already attained for bicycle work.

The recent great road races which have taken place in France and elsewhere have shown that the motor-car can be driven safely at a very high speed, already reaching in some cases seventy miles an hour; but to render this capacity for high speed useful, not only must special roads be provided on which these high-speed cars can travel without danger to others and with least slip and wear and tear of tyres, but a great deal requires to be done in the improvement of the pneumatic tyres, which at present get excessively hot, and therefore damaged by these high-speed runs. At these high speeds the mechanical work done on the material of which the outer covers of pneumatic tyres are composed is excessively high. It can probably be reduced by increasing the diameter of the wheels, but, of course, at the cost of increased weight and, to some extent, of stability, for the side strains on the wheels of these cars when swinging round curves of sharp radius are very great.

Another direction in which mechanical invention is required for the wheels of motor cars and wagons is a shoeing or protection of hard material of easily renewable character which can be firmly and safely attached to the outside of the tyre covers to take the wear and cutting action caused by the driving strain and by the action of the breaks on sudden stops.

The late R. W. Thomson, of Edinburgh, made good progress some thirty years ago in providing steel shoeing for the solid rubber tyres he then used, and the problems of providing the same for pneumatic tyres ought to be no harder than those he then successfully encountered.

One of the topics which has been most strongly discussed during the last year has been the position which this country holds relatively to other countries as regards its commercial supremacy in engineering matters. A few years back we were undoubtedly ahead of the world in most branches of mechanical engineering, but owing to the huge development of mechanical engineering in America and Germany, we are certainly being run very hard by these countries, and everyone is looking for means to help us to regain our old position. In endeavouring to learn from America we see that, although the workmen in that country receive higher wages than they do here, and although the cost of some of the materials is higher than it is here, their manufacturers manage to deliver engines, tools, and machinery of all classes of excellent quality at a price which appears to our manufacturers to be marvellously low. When we look into the matter we find that the chief difference between the manufacturer of America and the manufacturer at home is that, whether it be steam-engines, tools, agricultural machinery, or electrical machinery, the American invariably manufactures goods in large quantities to standard patterns, whereas we rarely do so here, at any rate to the same extent. Where we turn out articles by the dozen the American turns them out by the hundred. This difference in the extent to which an article is reduplicated is caused by the Americans having realised to a far greater extent than we have the advantage of standardisation of types of machinery. They have felt this so strongly that we find in America that work is far more specialised than it is here, so that a manufacturer as a rule provides himself with a complete outfit of machinery to turn out large numbers of one article. He lavishes his expenditure on special machinery to produce every part sufficiently accurate to dimension to secure thorough interchangeability; consequently the cost of erecting or assembling the parts is far less than it is here. One reason why the American manufacturer has been able to impose on his purchasing public his own standard types, whereas we

have not been able to do so, is that very rarely in America does a consulting engineer come between the manufacturer and the user, whereas here it is the fashion for the majority of purchasers of machinery to engage a consulting engineer to specify and inspect any machinery of importance. By this I do not impute any blame to our consulting engineer; he considers the requirements of his client, and insists that they are to be adhered to as closely as possible; to him the facility of the production of articles in large quantities is of no moment. In America it seems to be understood by the purchaser that it is a distinct advantage to everyone concerned, both manufacturer and purchaser, that the purchaser should to some extent give way and modify his requirements so as to conform with the standard patterns turned out by the manufacturer. Although manufacturers all hope for this simplification of patterns, yet, for the reasons I have given, it will be some time before their hope is realised. But on other matters it is quite possible for manufacturers to combine, so as to obtain some standardisation of parts which they manufacture which will reduce costs and be of advantage to everyone concerned. Many years ago Sir Joseph Whitworth impressed on the world the importance in mechanical engineering of extreme accuracy, and of securing the accurate fit and interchangeability of parts by standard gauges. But in spite of his idea being so widely known and taught, how seldom it has been acted upon to the extent that it should be. We pride ourselves on having all our screws made of Whitworth standard, and yet how many of the standard bolts and nuts made by different makers fit one another? I myself have sat on a committee of this Association which was called together twenty years ago, with Sir Joseph Whitworth as a member of it, to fix on a screw gauge which would be a satisfactory continuation of the Whitworth screw gauge down to the smallest size of screw used by watchmakers.[1] It has taken all these years to carry out the logical outcome of Sir Joseph Whitworth's original idea, viz., the providing of standards to be deposited in care of a public authority to act as standard gauges of references. The complete interchangeability of parts which I have above referred to, and which is so desirable in modern machinery, can, of course, be obtained within the limits of one works by that works providing and maintaining its own standards to a sufficient degree of accuracy. But if the articles be such as watches or bicycles, motor-cars, &c., it is very desirable that all parts liable to require replacement should be made by all manufacturers to one standard of size, and in order that the gauges required for this purpose should all be exact copies of one another it is necessary that they should be referable to gauges deposited either with the Board of Trade or with some body specially fitted to verify them and maintain their accuracy.

Up to the present the Board of Trade has dealt with the simple standards of weight, capacity, and length, but in other countries National Standardising Laboratories have been provided, viz., by the Germans at their Reichsanstalt at Charlottenburg, and with the happiest results; here at last, through the exertion of the Council of the Royal Society, our Government has been moved to give a grant in aid and to co-operate with the Royal Society to establish a National Physical Laboratory for this country. About ten years ago Dr. Oliver Lodge gave the outlines of a scheme of work for such an institution. Later Sir Douglas Galton, in his Presidential Address to this Association, called attention to the good work done by the Germans and the crying need that existed for such an institution in this country. The matter has since progressed. A laboratory is already in existence, and will soon be at work, at Bushy House, Teddington: it is a large residence, which was once occupied by the late Duke of Clarence and afterwards by the Duc de Nemours. It will make an admirable laboratory, as it has large and lofty rooms and a vaulted basement in which work can be carried on where it is important to secure the observer against changes of temperature.

The aims of a National Physical Laboratory have been well put forward by Dr. Glazebrook in a recent lecture at the Royal Institution, in which he points out how little science has up to the present come to be regarded as a commercial factor

[1] A report of this Committee will come before you during this meeting.

in our commercial world. The position of manufacturers of all classes must be helped and improved by a well-considered series of investigations on the properties of materials, measurements of forces, and by the careful standardisation of and granting certificates to measuring apparatus of all classes. Until the question is fairly faced and studied, few manufacturers realise how helpless individual effort or individual investigations must be when compared with comprehensive and continuous investigations which can be carried on by a National Laboratory so as to deal with the whole of each subject completely and exhaustively, instead of each investigation being limited by the temporary need of each manufacturer or user.

As an example Dr. Glazebrook showed how much has been done at Jena and afterwards at the Reichsanstalt in the development of the manufacture of glass used in all classes of scientific apparatus. The German glass trade has benefited enormously from these investigations. The microscopic examination of metals, which was begun by Sorby in 1864, has been much worked at by individual investigators in this country, but its further development, which is probably of enormous importance to arts and manufactures, is clearly the duty of a National Laboratory. We owe much to the investigations of the Alloys Research Committee of the Institution of Mechanical Engineers; but, again, this is work for the National Laboratory. As regards the measurement of physical forces how little is accurately known of the laws governing air resistance and wind-pressures, and the means of measuring them. Who can formulate with any certainty a law for the air resistances likely to be met with at speeds in excess of eighty miles an hour, the importance of which I have already noticed?

I have already alluded to the verification, care, and maintenance of ordinary standard gauges of accuracy. In this electrical age the accuracy of electric standards is of supreme importance.

These are only a few of the directions in which we can foresee that the establishment of a National Physical Laboratory will be of the greatest use and assistance to our country in enabling it to hold its own in scientific and engineering matters with its energetic rivals. The work has been commenced on a small scale, but it is to be hoped that its usefulness will become at once so evident and appreciated that it will soon be developed so as to be worthy of our country.

The following Papers were read:—

1. *The Mechanical Exhibits in the Glasgow Exhibition.* *By* D. H. Morton.

2. *Long continuous burning Petroleum Lamps for Buoys and Beacons.* *By* John R. Wigham.

3. *New Scintillating Lighthouse Light.* *By* John R. Wigham.

4. *A Recording Manometer for High-pressure Explosions.* *By* J. E. Petavel.

In this instrument the spring of the ordinary indicator is replaced by a metal cylinder. The travel of the piston is therefore limited to the amount allowed by the elastic compression of the metal (about one thousandth of an inch in the case of the present records).

The diagrams exhibited are typical of the results obtained: they both refer to a mixture of air and gas in the ratio of 6·4 to 1 fired at an initial pressure of about 1,190 lb. per sq. inch. In the second figure the speed of the chronograph has been greatly reduced so as to obtain a clear record of the rate of cooling.

FRIDAY, SEPTEMBER 13.

The following Report and Papers were read:—

1. *Report on the Resistance of Road Vehicles to Traction.*
See Reports, p. 402.

2. *Railway Rolling Stock, Present and Future.*
By NORMAN D. MACDONALD, *Advocate.*

In this paper the discussion is confined to rolling stock as used, and as likely to be used, in Great Britain, only touching upon the progress in other countries so far as it can be used to illustrate or provide hints for our future. Nor does it dwell on the present state of the art except so far as to show the future tendency. An attempt is made to raise points for thought and discussion rather than to give a lecture on the subject or to lay down laws and principles.

First, locomotives are treated on, and these under the various heads of shunting, mineral, goods, suburban, and express. Suggestions are made as to the best types for each in future, and the class of demands they will have to answer to. The question of compound *versus* simple is looked at, and also the matters of steam pressures, types of boilers, compensating levers (with special reference to the method in use on the New York Central and Hudson River Railroad for throwing extra weight on the drivers), water tubes, arrangements of fire-boxes, and all the details necessary to produce an efficient and powerful machine on our confined gauge. The various points observed at the Paris Exhibition for getting more power are touched upon. Also the modifications of designs necessary to obtaining a clear view ahead when a huge boiler is used. Reference is made to the use of auxiliary electric locomotives on grades. The various types, 'four-coupled,' 'ten-wheeled,' and 'Atlantic' for express locomotives are discussed. But in the whole paper no attempt is made to be technical or to descend to mere details. Locomotive tenders are briefly touched on with reference to track-tanks and their uses.

Next, passenger coaches are dealt with, including all questions of couplers, brakes, heating, and ventilation. The various types of trains and coaches—suburban, ordinary local, and express; sleeping cars (first and third), dining cars, buffet cars, kitchen cars, and a new type for suburban trains, with references to United States, Russian, and Continental practice and progress—are fully discussed. The coming competition of electric trams and motor-cars for suburban traffic compels the consideration of new types of rolling stock for competitive purposes. High-speed brakes for special stock are touched on.

Lastly, goods and mineral waggons claim attention, and in regard to these, economical transport in larger units, couplers, continuous brakes, and all the various questions of quick handling and quick transport are looked at. A cross between United States and British practice is advocated, and the examples of such from the colonies are adduced in illustration.

3. *The Panama Canal. By* P. BUNAU VARILLA.

4. *On a Leaf-arrestor, or Apparatus for removing Leaves, &c., from a Water Supply. By* THE EARL OF ROSSE.

Having recently erected a turbine of 15 h.p., with 8-foot fall, for working an electric light installation at Birr Castle, I found, as I had anticipated, considerable trouble through leaves, &c., choking the screen in the water supply, so much so that during the fall of the leaf last autumn the output was generally reduced to one half in the course of half or three-quarters of an hour's working unattended, notwithstanding that the area of the screen was nearly a hundred square feet.

Accordingly an apparatus was devised for remedying the evil. It was so successful that the turbine would go for a whole day without attention and without diminution of output from the above cause.

The apparatus consists of a cylinder of wire gauze, of 4 feet diameter and 4½ feet height, set in an opening in a vertical diaphragm extending across the supply drain and revolving twice in a minute or so round a vertical axis. The current flows through the gauze cylinder in a horizontal direction. The leaves, carried down with the current, attach themselves under pressure of the stream, are carried round till they reach the diaphragm, which on that side is double, with an intervening space of some ten inches, which is connected with the tail-race; and at this point, the current through the gauze being reversed, the leaves are detached and are carried by a portion of the water towards the tail-race. Four or five per cent. of the supply is ample for conveying the leaves; probably much less would suffice. A very few leaves get past and on to the screen, but so few that they give no trouble.

The apparatus has also been constructed of the disc form, and also as a cylinder on a vertical axis, the water entering all round, except along one vertical section connected with the tail-race as before, and bearing vertically downwards round the axis; but only as working models, and on this scale they are even more effectual in their action. But there seemed no sufficient reason for modifying the full-sized apparatus, which has now been in action for nearly a year, and has given complete satisfaction.

SATURDAY, SEPTEMBER 14.

The Section did not meet.

MONDAY, SEPTEMBER 16.

The following Papers were read:—

1. *The Protection of Buildings from Lightning.* *By* KILLINGWORTH HEDGES, *M.Inst.C.E., M.I.E.E.*

The last time this subject was brought before this Association was at the Bath meeting in 1888, when a joint discussion of Sections A and G was held; but there has been no official report as to the effect of lightning stroke upon buildings protected by conductors since the Lightning Rod Conference of 1882. Interest in the subject has been again revived, first, by the Electro-Technische Verein of Berlin, who have this year published a set of rules; and secondly, by the establishment in this country of the Lightning Research Committee, organised jointly by the Royal Institute of British Architects and the Surveyors' Institute.

The author compares Continental and American practice, and gives an account of his rearrangement of the system used at St. Paul's Cathedral, where the conductors, erected as recently as 1872, were found to be totally inefficient, both as regards the conductivity of the joints and the resistance of the earth connections. In the plan recommended, both for this installation and for the more recent one at Westminster Abbey, the number of ordinary conductors from air to earth has been greatly increased, and, besides these, horizontal cables are run on the ridges of the roofs and in other prominent positions so as to encircle the building, being interconnected to the vertical conductors wherever they cross one another. The horizontal cables are furnished at intervals with aigrettes, or spikes, which are invisible from the ground level, and are designed to give many points of discharge. At the same time they, in conjunction with the cables, would receive

any side flash which might occur should any portion of the building receive a direct stroke of lightning.

The unreliability of soldered joints for conductors, whether of cable or tape, has led the author to design a special joint box, which can be applied for uniting any portion of the system together in such a manner as to give great mechanical strength as well as good electrical contact; at the same time any box can have points inserted so as to form an aigrette in any desired position.

Owing to the difficulty of sinking an earth plate of sufficient area, on account of old foundations, a special form of tubular earth has been designed which takes up little space and has the advantage that if a suitable moist ground is not obtainable the desired low electrical resistance is attained by leading a tube in connection with the rain-water pipes, so that a portion of the rainfall is diverted to the tubular earth.

The author alludes to the immense amount of damage to property annually occurring which might be prevented if efficient conductors were installed. He mentions that instead of every church having its lightning conductor not ten per cent. are so provided; and in the case of other public buildings the percentage is not much larger, the reason in the case of the former class of buildings being that a vicar wishing to safeguard his church has usually to pay the cost out of his own pocket.

Architects, as a rule, treat the question of lightning conductors in a very brief manner, and in their specifications seldom say anything as to the way in which they are to be run, or the necessity for good joints and good earth connections.

2. *The Commercial Importance of Aluminium.*
By Professor Ernest Wilson, *M.I.E.E.*

During the last ten years enormous progress has been made in the production of aluminium. In 1900 no less than 5,000 tons were produced by plants having 25,000 horse-power, representing a capital of 2,000,000*l.* All aluminium may be said to be produced by the electrolytic method, which was patented by Hall in America and Hérault in England and France in 1886-1887. After giving a short *résumé* of the progress in manufacture, and a description of the electrolytic cell, the author discussed the properties of the metal. From experiments made at King's College, London, it appears that aluminium containing ·31 per cent. Fe and ·14 per cent. Si has a specific resistance of $2{\cdot}76 \times 10^{-6}$ ohms at 15° C., which shows that its conductivity is about 61·5 per cent. that of copper, taking Matthiessen's standard. In the form of wire ·126 in. diameter the breaking load is 12·6 tons per square inch, the limit of elasticity 8·65 tons per square inch, and percentage extension within the limit of elasticity ·19, with an applied force of 7·2 tons per square inch. Some copper and nickel copper alloys give 20 tons per square inch, 16 tons limit of elasticity, ·19 per cent. extension within the limits of elasticity under an applied force of 7·2 tons per square inch, with a conductivity 52 per cent. of that of copper. The Standard Electric Company of California in their 43 miles transmission line are stated to use aluminium having 10·1 tons per square inch breaking load, and a conductivity 59·9 per cent. of copper.

The weight of a given volume of a metal may govern its financial value. Since copper is 3·37 times as heavy as aluminium it follows that, volume for volume, aluminium at 130*l.* per ton is cheaper than copper at 70*l.* per ton.

For equal conductivity the relative weights would be 1 of copper to ½ of aluminium, and the diameter of the aluminium wire would be 1·27 time that of the copper.

Dealing with wind pressure the author stated that the total tensile strength of an aluminium wire of the same conductivity as copper may be greater than that of the copper, and this may compensate for increase in the surface exposed to wind, snow, &c.

A short description of some long-distance transmission lines was given, showing that aluminium is being installed with success. It was stated that joints

which are mechanical in the above cases can be made with success. It was pointed out that aluminium can be welded and soldered. The melting and casting, rolling and forging, hardening and annealing, of aluminium were next dealt with.

Probably the widest field is still in the purification of iron and steel. At high temperatures the metal decomposes nearly all metallic oxides, and prevents blow-holes by combining with the gases which form the holes.

The author referred to the use of aluminium when alloyed with copper for the production of aluminium bronzes. The breaking load varies from 44 to 39 tons per square inch in the case of alloys containing 8 to 12 per cent. aluminium. It has a golden appearance, and is suitable for hydraulic work on account of its non-corrodible properties.

3. *Recent Observations on Bridges in Western China.* *By* R. LOCKHART JACK, *B.E.*

During 1900, while travelling in the West of China, in Szechuan and Yunnan, I was struck by the variety of Chinese bridges, ranging as they do from pontoons and even large baskets of shingle supporting a temporary decking, to stone and iron bridges of large span.

On the headwaters of the Min, Fou, and Mekong rivers the single rope bridge is used, on which the traveller, by the aid of a runner to which he is fastened, crosses from one bank to the other. The rope is of plaited bamboo, from two to three inches in diameter, while the runner employed is a half cylinder of hard wood ten inches long.

The bamboo is also much employed for suspension bridges, a very good example of which is to be found at Shih Chuen. It is composed of sixteen hawsers, each from 7 to 8 inches in diameter, tightened by capstans, and is 240 feet long by ten wide. The decking, of wicker work, is laid upon fourteen of these hawsers, the other two acting as guard rails. The bridges are entirely renewed at intervals of one to three years.

In other districts suspension bridges are built of wrought iron, chains or bars, the decking following the curvature of the chains, which, however, is very slight, that of the Yangtse near Likiang being less than 20 feet on a span of 320. This bridge, the largest single span we saw, is built up of eighteen chains, the links of which were 11 inches long of 1¼ inch bar iron. The chains are anchored to castings bedded in the masonry abutments, and are tightened by driving wedges between the links. This type of bridge is said to have been in existence at about the beginning of the Christian era, and possibly much earlier.

Cantilevers and trestle bridges are used where timber is plentiful, the latter being generally covered with a tiled roof and lined at the sides with stalls. The timber is mostly soft wood, but they last very well owing to the protection afforded by the roof.

The greatest triumphs of the Chinese, however, are their masonry bridges, which are exceedingly numerous in the wealthier districts of Szechuan. Broadly, they are of two kinds: those in which slabs of stone are used as girders, and those which embody the principle of the arch. A good example of the former was being erected at Chiung Chow, 50 miles S.W. of Chengtu, and consisted of a bridge nearly 700 feet long by 15 wide, formed of stone slabs laid on edge, and carried on thirty-three tiers, each 40 feet by 4. The whole of the stone used was a red sandstone cut into blocks.

Of the arch bridges the largest is at Ning Shih, also of sandstone, where a bridge about 600 feet long (including masonry approaches) is carried across a tributary of the Yangtse Kiang on three spans of over 100 feet each.

One-arch bridges with the roadway rising to the centre by steps are very common over small streams, and bridges of twelve to eighteen arches are occasionally met with.

There is reason to believe that the Chinese used such bridges as have been described at a very early period, and it would be of interest to make a study of

their works, and so see if they are built in accordance with some definite rule or formula, or if they have learned by long experience what is safe for each type and each material.

4. *On Recording Soundings by Photography.* *By* J. Dillon.

5. *On the Size of Waves as observed at Sea.* *By* Vaughan Cornish, *D.Sc.*

The Height of Waves.—The height of the ocean waves in deep water from land has been determined with fairly concordant results by independent observers. The values recorded are the average of the heights of a number of successive waves:—

Heights in Feet.

	Desbois	Paris	Wilson-Barker	Mean
Hurricane	28·54	25·43	28	27·32
Strong gale . . .	20·64	16·57	23	20·07
Gale.	15·42	—	14	14·71
Strong breeze . . .	10·83	—	8	9·415

These values are only about one-half of the 40 or 50 feet which experienced seamen frequently state to be 'the size of the waves' met with in strong gales in the open ocean. The author has observed during gales in the North Atlantic that waves of a larger size recurred at short intervals, and that it was these which riveted the attention and which were dangerous. He thinks that it is the average size of these 'ordinary maximum' waves which is commonly estimated by seamen as 40 to 50 feet, and he suggests that it is desirable to record in future, not only the general average height, but also the height of the 'ordinary maximum' waves. This practice would do away with much of the apparent discrepancy between the accounts of the size of waves at sea, and would also give some notion of the simultaneous differences of roughness at different points, which is an important aspect of a sea-way.

The Length of Waves.—The highest waves in deep water are recorded during storms, but the longest are the swells encountered in a calmer atmosphere. At sea, where the ship rises and falls, and there is no fixed object to provide a datum line, crests and troughs are judged less by actual elevation than by convexity or concavity of the water's surface. When the profiles of two waves of nearly equal amplitude but of very different wave-length are combined, the resulting wavy line presents a series of inequalities the wave-length of which is fairly regular, and equal, on an average, to that of the shorter component. When, however, the two combining waves, of very different wave-length, are of equal *steepness*, the combination appears as a series of inequalities which, although displaying minor sinuosities of outline, have unmistakably the wave-length of the *longer* component. Their average amplitude is also equal to that of the longer component. This indicates (*a*) that a swell, even of great amplitude, is not directly measureable in a storm; (*b*) that a great swell scarcely affects the recorded average height and length of the shorter storm-waves, but that it can cause irregularity of the kind referred to in the last section; and (*c*) that the appearance of the water may change somewhat suddenly from that of an irregular short sea to that of an irregular long swell, the longer component being now what the author terms 'the dominant wave.' This change of appearance is not, however, accompanied by any acceleration of the processes going on in the wave-water.

The following Report and Papers were read:—

1. *Report on the Small Screw Gauge.*—See Reports, p. 407.

2. *A Portable folding Range-Finder, for Use with Infantry. By* G. FORBES, *F.R.S.*

3. *Machinery for Engraving. By* MARK BARR.

4. *Recent Developments of Chain Driving. By* C. R. GARRARD.

5. *Measurement of the Hardness of Materials by Indentation by a Steel Sphere. By* T. A. HEARSON.

6. *On the Critical Point in Rolled Steel Joists. By* E. J. EDWARDS.

In selecting rolled steel joists for floors there are two elements which determine the section to be used with a given load per square foot of floor area.

First, the stress per square inch produced by the load.

Second, the deflection produced by the same load.

At first, particularly with small spans, it is the stress per square inch which is the governing element: this stress must not exceed safe working limits. As the floor span is increased the deflection becomes the ruling element, the stress per square inch falling into the background.

The deflection must not be sufficient to crack the ceiling where there is one, nor sufficient to be unsightly where there is none.

In the diagrams exhibited two curves are shown, one in black and the other in red. The former is the curve of a given maximum stress, and shows the loads a steel joist will carry for various spans. The red curve gives the loads which produces a deflection which is a constant given fraction of the span, viz., $\frac{1}{360}$.

The curves cross each other, and the point of crossing the author calls the critical point. At this point the distributed load produces the given stress and given deflection. Before the critical point is reached the load produces the specified stress, but is insufficient to produce the limiting deflection; after the critical point is passed the distributed load produces the specified deflection, but is insufficient to produce the specified stress; in other words, the limit of deflection is reached before the limit of stress. Examples are given of various sizes of steel joists with the limiting stresses and deflections.

Generalising, up to the critical point the stress curve is the more important; beyond this the deflection curve is more important. The two important parts of the curves taken together are called the curve of loads, which is a curve with a kink in it.

The first part of curve is drawn from the formula $W = \frac{128I}{9Ld}$ and the second part from the formula $W = \frac{32I}{L^3}$. Explanations showing how the equations are arrived at are given in the paper.

With a factor of safety of 3 and a breaking stress of 32 tons per square inch, and a deflection of $\frac{1}{360}$ span, the critical point is at a span of twenty-seven times

the depth. For this particular deflection it is shown that the factor of safety multiplied by 9 gives the critical point.

If the deflection in percentages of the span are calculated a series of curves of deflection can be plotted. At 1 ton per square inch and 1 per cent. of deflection the critical point is 576, the depth at 2 per cent. of deflection, the critical point is 288 times the depth, or 9×32. As at 1 ton per square inch, 32 is the factor of safety.

The values are tabulated and shown graphically by diagrams.

Returning to the special object of the paper, the selecting of rolled steel joists for fireproof floors, the principal step is to determine the pitch or spacing apart of the joists.

These pitches are tabulated for various sections of joists for the loads of 1 cwt. and $1\frac{1}{4}$ cwt. per square foot of floor. A formula is deduced for a loading of 1 cwt. per square foot: $p = \frac{20W}{L}$, and for any other loading $p_x = \frac{p}{x}$, where x is the cwts. of load per square foot, p = pitch in feet, L = span in feet, and W = distributed load in tons, the rolled steel joist will carry safely.

A final result is that the pitch varies inversely as the square of the span when the stress per square inch is considered, *i.e.*, up to the critical point, and varies inversely as the cube of the span when the deflection is considered or beyond the critical point.

7. *On Alternating Air Currents in Churches and Public Buildings.* *By* J. W. THOMAS, *F.I.C.*, *F.C.S.*

When the temperature of the air outside is 35° F. or less, the exit space for foul air in a great number of churches and public buildings is too large to keep back the extra pressure outside, and cold air enters the top of the building at the points of least friction and resistance the large openings generally. In high buildings the cold air currents, or down-draughts, are followed by hot and oppressive waves of air, after which the air becomes motionless and stagnant for some seconds.

Some years ago the author experimented in a large public hall, and found that these hot and cold experiences were due to alternating air currents in the building. Taking the point of the least internal pressure as the first observation, it took about half a minute to reach the point of highest internal pressure, and rather less than half a minute afterwards to reach the point of least pressure again. The first five seconds after the least internal pressure was reached there was a gradual rise, followed by double such an interval of more rapid increase; then there were a few seconds of lesser increase, followed by a lengthened period, during which the pressure-recording instrument remained almost steady. When the reduction of internal pressure began much cold air still descended, and there were ten or more seconds during which the reduction was gradual: then, for about half that period, a very rapid decrease occurred, followed by several seconds when the instrument was steady and almost stationary at the point of least pressure.

The strangest fact in the results obtained was that, owing to the elasticity of the air, its density (32° F. outside), and the velocity obtained by falling about 60 feet, the pressure increased internally until it *actually exceeded the pressure outside* for a few seconds, then decreased and increased alternately.

Since then experiments in high churches and buildings have given similar results. An anemometer held in a narrow opening in a doorway leading to a church turned rapidly inwards, indicating an up-current; then it stopped and subsequently reversed, showing that the pressure in the building was acting outwards.

Air inlets to hot-water pipes under the floor of a building are influenced by alternating air currents at their highest pressure, and when the period of greatest upward movement occurs, such a deluge of cold air passes inwards that the inlets have to be shut.

Alternating air currents, therefore, greatly impair the ventilation of buildings.

SECTION H.—ANTHROPOLOGY.

PRESIDENT OF THE SECTION—Professor D. J. CUNNINGHAM, M.D., D.SC., LL.D., D.C.L., F.R.S.

THURSDAY, SEPTEMBER 12.

The President delivered the following Address:—

TWENTY-FIVE years have passed since the British Association met in Glasgow. This is a long time to look back upon, and yet the period appears short when measured by the great advance which has taken place in almost all branches of knowledge. Anthropology has shared in the general progress. The discoveries made within its confines may not have been so startling, nor yet have had such a direct influence upon the material welfare of the people, as in the case of other fields of scientific study, but its development has been steady and continuous, and it has grown much in public estimation.

At the Glasgow Meeting of the Association in 1876 Anthropology held a subsidiary position. It only ranked as a Department, although it gained a special prominence through having Alfred Russel Wallace as its Chairman. It was not until several years later that it became one of the recognised Sections of the Association, and attained the high dignity of having a letter of the alphabet allotted to it. But quite independently of its official status it has always been a branch of study which has been accorded a large amount of popular favour. The anthropological meetings have, as a rule, been well attended, and the discussions, although perhaps on certain occasions somewhat discursive, have never lacked vigour or animation. Professor Huxley, who presided over the Anthropological Department at the Dublin meeting in 1878, ascribed the popularity of the subject to the many openings which it affords for wide differences of opinion between the exponents of its numerous branches and to the innate bellicose tendency of man. As the representative of a country in which, according to the same high authority, this tendency is less strongly marked than elsewhere, and of a race which has so frequently and pointedly exhibited its abhorrence of vigorous language, I trust that my presence here as President may not react unfavourably on the interest shown in the work of the Section.

The present occasion might appear to be peculiarly appropriate for my taking stock of our anthropological possessions and summing up the numerous additions to our knowledge of 'man and his doings' which have been made during the century which has just passed. Such a task, however, is surrounded with so much difficulty that I shrink from undertaking it. The scope of the subject is enormous, and the studies involved so diverse and so varied that I feel that it is beyond my power to give any comprehensive survey of its development in all its parts. I prefer therefore to confine my remarks to that province of Anthropology within which my own work has been chiefly carried on, and from this to select a subject which has for some years held a prominent place in my thoughts. I refer to the human brain and the part which it has played in the evolution of man.

One of the most striking peculiarities of man when regarded from the structural point of view is the relatively great size of his brain. Although with one or two exceptions the several parts of the brain are all more or less involved in this special development, it is the cerebral hemispheres which exhibit the preponderance in the highest degree. This characteristic of the human brain is rendered all the more significant when we consider that the cerebral hemispheres cannot be looked upon as being primitive parts of the brain. In its earliest condition the brain is composed of three simple primary vesicles, and the cerebral hemispheres appear in a secondary manner in the shape of a pair of lateral offshoots or buds which grow out from the foremost of these primitive brain-vesicles.

The offshoots which form the cerebral hemispheres are found in all vertebrates. Insignificant in size and insignificant in functional value in the more lowly forms, a steady increase in their proportions is manifest as we ascend the scale, until the imposing dimensions, the complex structure, and the marvellous functional potentialities of the human cerebral hemispheres are attained. In their development the cerebral hemispheres of man rapidly outstrip all the other parts of the brain until they ultimately usurp to themselves by far the greater part of the cranial cavity. To the predominant growth of the cerebral hemispheres is due the lofty cranial vault of the human skull: to the different degrees of development and to the different forms which they assume are largely due the variations in cranial outline in different individuals and different races—variations in the determination of which the Craniologist has laboured so assiduously and patiently.

I think that it must be manifest to everyone that the work of the Craniologist, if it is to attain its full degree of usefulness, must be founded upon a proper recognition of the relation which exists between the cranium and the brain, or, in other words, between the envelope and its contents.

The cranium expands according to the demands made upon it by the growing brain. The initiative lies with the brain, and in normal conditions it is questionable if the envelope exercises more than a very subsidiary and limited influence upon the form assumed by the contents. The directions of growth are clearly defined by the sutural lines by which the cranial bones are knit together; but these are so arranged that they admit of the expansion of the cranial box in length, in breadth, and in height, and the freedom of growth in each of these different directions has in all probability been originally determined by the requirements of the several parts of the brain.

The base or floor of the cranium, supporting as it does the brain-stem or the parts which possess the greatest phylogenetic antiquity, and which have not undergone so large a degree of modification in human evolution, presents a greater uniformity of type and a greater constancy of form in different individuals and different races than the cranial vault which covers the more highly specialised and more variable cerebral hemispheres.

To what extent and in what directions modifications in the form of the cranium may be the outcome of restrictions placed on the growth of the brain it is difficult to say. But, broadly speaking, I think we may conclude that the influence which the cranium, under normal circumstances, independently exerts in determining the various head-forms is trifling.

When we speak therefore of brachycephalic or short heads, and dolichocephalic or long heads, we are merely using terms to indicate conditions which result from individual or racial peculiarities of cerebral growth.

The brachycephalic brain is not moulded into form by the brachycephalic skull; the shape of both is the result of the same hereditary influence, and in their growth they exhibit the most perfect harmony with each other.

Craniology has been called the 'spoiled child of Anthropology.' It is supposed that it has absorbed more attention than it deserves, and has been cultivated with more than its share of care, while other fields of Anthropology capable of yielding rich harvests have been allowed to remain fallow. This criticism conveys a very partial truth. The cranium, as we have seen, is the outward expression of the contained brain, and the brain is the most characteristic organ of man; cranial peculiarities therefore must always and should always claim a leading place in the mind of the

ologist; and this is all the more imperative seeing that brains of different races are seldom available for investigation, whilst skulls in the different museums may literally be counted by thousands.

Meantime, however, the Craniologist lies buried beneath a mighty mountain of figures, many of which have little morphological value and possess no true importance in distinguishing the finer differences of racial forms. Let us take as an example the figures upon which the cephalic or length-breadth index of the skull is based. The measurement of the long diameter of the cranium does not give the true length of the cranial cavity. It includes, in addition, the diameter of an air-chamber of very variable dimensions which is placed in front. The measurement combines in itself therefore two factors of very different import, and the result is thereby vitiated to a greater or less extent in different skulls. A recent memoir by Schwalbe[1] affords instructive reading on this matter. One case in point may be given. Measured in the usual way, the Neanderthal skull is placed in the dolichocephalic class; whereas Schwalbe has shown that if the brain-case alone be considered it is found to be on the verge of brachycephaly. Huxley, many years ago, remarked that 'until it shall become an opprobrium to an ethnological collection to possess a single skull which is not bisected longitudinally' in order that the true proportions of its different parts may be properly determined we shall have no 'safe basis for that ethnological craniology which aspires to give the anatomical characters of the crania of the different races of mankind.' It appears to me that the truth of this observation can hardly be disputed, and yet this method of investigation has been adopted by very few Craniologists.

It has become too much the habit to measure and compare crania as if they were separate and distinct entities and without a due consideration of the evolutionary changes through which both the brain and its bony envelope have passed. Up to the present little or no effort has been made to contrast those parts of the cranial wall or cavity which have been specially modified by the cerebral growth-changes which are peculiar to man. It may be assumed that these changes have not taken place to an equal extent, or indeed followed identically the same lines in all races.

Unfortunately our present knowledge of cerebral growth and the value to be attached to its various manifestations is not so complete as to enable us to follow out to the full extent investigations planned on these lines. But the areas of cerebral cortex to which man owes his intellectual superiority are now roughly mapped out, and the time has come when the effect produced upon the cranial form by the marked extension of these areas in the human brain should be noted and the skulls of different races contrasted from this point of view.

To some this may seem a return to the old doctrine of Phrenology, and to a certain extent it is; but it would be a Phrenology based upon an entirely new foundation and elaborated out of entirely new material.

It is to certain of the growth changes in the cerebrum which I believe to be specially characteristic of man, and which unquestionably have had some influence in determining head-forms, that I wish particularly to refer in this Address.

The surface of the human cerebrum is thrown into a series of tortuous folds or convolutions separated by slits or fissures, and both combine to give it an appearance of great complexity. These convolutions were long considered to present no definite arrangement, but to be thrown together in the same meaningless disorder as is exhibited in a dish of macaroni. During the latter half, or rather more, of the century which has just ended it has, however, been shown by the many eminent men who have given their attention to this subject that the pattern which is assumed by the convolutions, while showing many subsidiary differences, not only in different races and different individuals, but also in the two hemispheres of the same person, is yet arranged on a consistent and uniform plan in every human brain, and that any decided deviation from this plan results in an imperfect carrying out of the cerebral function. In unravelling the intricacies of the human

[1] *Studien über Pithecanthropus erectus* (Dubois). *Zeitschrift f. Morph. und Anthrop.*, Band I, Heft 1, 1899.

convolutionary pattern it was very early found that the simple cerebral surface of the ape's brain in many cases afforded the key to the solution of the problem. More recently the close study of the manner in which the convolutions assume shape during their growth and development has yielded evidence of a still more valuable kind. We now know that the primate cerebrum is not only distinguished from that of all lower mammals by the possession of a distinct occipital lobe, but also by having imprinted on its surface a convolutionary design, which in all but a few fundamental details is different from that of any other order of mammals.

There are few matters of more interest to those anthropologists who make a study of the human skull than the relationship which exists between the cranium and the brain during the period of active growth of both. Up to the time immediately prior to the pushing out of the occipital lobe, or, in other words, the period in cerebral development which is marked by the transition from the quadrupedal type to the primate type of cerebrum, the cranial wall fits like a tight glove on the surface of the enclosed cerebrum. At this stage there would appear to be a growth antagonism between the brain and the cranial envelope which surrounds it. The cranium, it would seem, refuses to expand with a speed sufficient to meet the demands made upon it for the accommodation of the growing brain. In making this statement it is right to add that Hochstetter, in a carefully reasoned memoir, has recently cast doubt upon the reality of the appearances which have led to this conclusion, and at the recent meeting of the Anatomische Gesellschaft, in Bonn, Professor Gustaf Retzius,[1] one of the numerous observers responsible for the description of the early cerebrum upon which the conclusion is based, showed some inclination to waver in his allegiance to the old doctrine. This is not the time nor the place to enter upon a discussion of so technical a kind, but I may be allowed to say that whilst I fully recognise the necessity for further and more extensive investigation into this matter I do not think that Hochstetter has satisfactorily accounted for all the circumstances of the case.

When the occipital lobe assumes shape the relationship of the cranial wall to the enclosed cerebrum undergoes a complete change. The cranium expands so rapidly that very soon a wide interval is left between the surface of the cerebrum and the deep aspect of the cranial envelope within which it lies. This space is occupied by a soft, sodden, spongy meshwork, termed the subarachnoid tissue, and it is into the yielding and pliable bed thus prepared that the convolutions grow. At first the surface of the cerebral hemisphere is smooth, but soon particular areas of the cortex begin to bulge out and foreshadow the future convolutions. These suffer no growth restriction, and they assume the form of round or elongated elevations or eminences which rise above the general surface level of the cerebral hemisphere and break up its uniform contour lines in the same manner that mountain chains protrude from the surface of the globe.

As growth goes on, and as the brain gradually assumes a bulk more nearly in accord with the cavity of the cranium, the space for surface protrusions of this kind becomes more limited. The gyral elevations are now pressed together: they become flattened along their summits, and in course of time they acquire the ordinary convolutionary shapes. While this is going on the valleys or intervals between the primitive surface elevations become narrowed, and ultimately assume the linear slit-like form characteristic of the fissures. These changes occur shortly before birth, but are not fully completed until after the first few months of infancy. The final result of this process is that the convolutions come into intimate relation with the deep aspect of the cranial wall and stamp their imprint upon it.

It is obvious that certain of the later changes which I have endeavoured to portray might be ascribed to a growth antagonism between the brain and the enclosing cranium at this period. In reality, however, it is merely a process by which the one is brought into closer adaptation to the other—a using up, as it were, of superfluous space and a closer packing together of the convolutions—after the period of active cortical growth is past. Nevertheless the convolutionary pattern is profoundly affected by it, and it seems likely that in this process we find the

[1] Anatomische Gesellschaft, Bonn, May 28, 1891. Gustaf Retzius, *Transitorische Furchen des Grosshirns.*

explanation of the different directions taken by the cerebral furrows in brachycephalic and dolichocephalic heads.

The cortical elevations which rise on the surface of the early cerebrum are due to exuberant growth in localised areas. There cannot be a doubt that the process is intimately connected with the development of function in the districts concerned. We know that functions of different kinds are localised in different parts of the cortex, and when we see an area on the surface of the early cerebrum rise up in the form of an eminence we may reasonably conclude that the growth in the area concerned is the structural foundation of what will become later on a centre of functional activity of an acute kind.

A consideration of this matter gives the clue to the simple convolutions of the ape and the complex convolutions of man, and, further, it explains how the interrupted form of fissural development is one of the essential characteristics of the human brain as compared with the simian brain. Areas which rise up in the form of one long elevation on the surface of the ape's brain appear in the form of several eminences on the surface of the human brain, and fissures which appear in the form of long continuous slits in the simian cerebrum appear in the human cerebrum in several detached bits, which may or may not in the course of time run into each other and become confluent. All this is due to the greater definition, refinement, and perfection of the functions carried on in the cerebral cortex of man. It is an index of a more complete 'physiological division of labour' in the human brain.

It is not necessary, for the purpose I have in view, to enter into any detail regarding the many points of difference which become evident when the cerebral surface of the ape is compared with that of man. It is more my purpose to indicate certain of the districts of cerebral cortex which have undergone a marked increase in the human brain—an increase which may be reasonably supposed to be associated with the high mental attributes of man. To us, at the present time, it is difficult to conceive how it was ever possible to doubt that the occipital lobe is a distinctive character of the simian brain as well as of the human brain, and yet at successive meetings of this Association (1860, 1861, and 1862) a discussion, which was probably one of the most heated in the whole course of its history, took place on this very point. One of our greatest authorities on animal structure maintained that the occipital lobe and the hippocampus minor—an elevation in its interior—were both peculiar to man and to him alone. Everyone has read in the 'Water Babies' Charles Kingsley's delightful account of this discussion. Speaking of the Professor he says: 'He held very strange theories about a good many things. He had even got up at the British Association and declared that apes had hippopotamus majors in their brains just as men have. What a shocking thing to say; for if it were so, what would become of the faith, hope, and charity of immortal millions? You may think that there are other more important differences between you and an ape, such as being able to speak, and make machines, and know right from wrong, and say your prayers, and other little matters of that kind; but that is a child's fancy.' In the light of our present knowledge we can fully understand Professor Huxley closing the discussion by stating that the question had 'become one of personal veracity.' Indeed, the occipital lobe, so far from being absent, is developed in the ape to a relatively greater extent than in man, and this constitutes one of the leading positive distinctive characters of the simian cerebrum. Measured along the mesial border, the percentage length of the occipital lobe to the total length of the cerebrum in the baboon, orang, and man is as follows:—

Baboon	29·7
Orang	23·2
Man	21·2

But these figures do not convey the full extent of the predominance of the occipital lobe in the ape. The anterior border of the lobe grows forwards beyond its proper limits, and pushes its way over the parietal lobe which lies in front, so as to cover over a portion of it by an overlapping lip termed the occipital

operculum. There is not a trace of such an arrangement in the human brain, and even in the anthropoid ape the operculum has become greatly reduced. Indeed, in man there is exactly the reverse condition. The great size of the parietal lobe is a leading human character, and it has partly gained its predominance by pushing backwards so as to encroach, to some extent, upon the territory which formerly belonged to the occipital lobe.[1] A great authority[2] on the cerebral surface refers to this as a struggle between the two lobes for surface extension of their respective domains. 'In the lower apes,' he says, 'the occipital lobe proves the victor: it bulges over the parietal lobe as far as the first annectant gyrus. Already, in the orang, the occipital operculum has suffered a great reduction; and in man the victory is on the side of the parietal lobe which presses on the occipital lobe and begins, on its part, to overlap it.' Now that so much information is available in regard to the localisation of function in the cerebral cortex, and Flechsig has stimulated our curiosity in regard to his great 'association areas' in which the higher intellectual powers of man are believed to reside, it is interesting to speculate upon the causes which have led to the pushing back of the scientific frontier between the occipital and parietal cerebral districts.

The parietal lobe is divided into an upper and a lower part by a fissure, which takes an oblique course across it. Rudinger,[3] who studied the position and inclination of this fissure, came to the conclusion that it presents easily determined differences in accordance with sex, race, and the intellectual capacity of the individual. He had the opportunity of studying the brains of quite a number of distinguished men, amongst whom were Bischoff of Bonn, Döllinger of Munich, Tiedemann of Heidelberg, and Liebig of Munich, and he asserts that the higher the mental endowment of an individual the greater is the relative extent of the upper part of the parietal lobe.

There is absolutely no foundation for this sweeping assertion. When the evolutionary development of the parietal part of the cerebral cortex is studied exactly the reverse condition becomes manifest. It is the lower part of the parietal lobe which in man, both in its early development and in its after growth, exhibits the greatest relative increase. Additional interest is attached to this observation by the fact that recently several independent observers have fixed upon this region as one in which they believe that a marked exuberance of cortical growth may be noted in people of undoubted genius. Thus Retzius has stated that such was the case in the brains of the astronomer Hugo Gyldén,[4] and the mathematician Sophie Kovalevsky;[5] Hansemann[6] has described a similar condition in the brain of Helmholtz; and Guszman[7] in the brain of Rudolph Lenz, the musician. Some force is likewise added to this view by Flechsig, who, in a recent paper,[8] has called attention to the fact that within this district there are located two of his so-called 'Terminalgebiete,' or cortical areas, which attain their functional powers at a later period than those which lie around them, and which may therefore be supposed to have specially high work to perform.

Without in any way desiring to throw doubt upon the observations of these authorities, I think that at the present moment it would be rash to accept, without

[1] It is necessary to emphasise this point, because in Wiedersheim's *Structure of Man* we are told that in man there is a preponderance of the occipital lobe, and that the parietal lobe is equally developed in man and anthropoids.

[2] Eberstaller, *Wiener Medizinische Blätter*, 1884, No. 19, p. 581.

[3] *Beiträge zur Anatomie und Embryologie*, als Festgabe Jacob Henle, 1882.

[4] Retzius, *Biologische Untersuchungen*, neue Folge, viii. 1898, 'Das Gehirn des Astronomen Hugo Gyldéns.'

[5] Retzius, *Biologische Untersuchungen*, neue Folge, ix. 1900, 'Das Gehirn der Mathematikerin Sonja Kovalevsky.'

[6] Hansemann, *Zeitschrift für Psychologie und Physiologie der Sinnesorgane*, Band xx. Heft 1, 1899, 'Ueber das Gehirn von Hermann v. Helmholtz.'

[7] Josef Guszman, *Anatomischer Anzeiger*, Band xix. Nos. 9 and 10, April 1901, 'Beiträge zur Morphologie der Gehirnoberfläche.'

[8] Flechsig, 'Neue Untersuchungen über die Markbildung in den menschlichen Grosshirnlappen,' *Neurologisches Centralblatt*, No. 21, 1898.

further evidence, conclusions which have been drawn from the examination of the few brains of eminent men that have been described. There cannot be a doubt that the region in question is one which has extended greatly in the human brain, but the association of high intellect with a special development of the region is a matter on which I must confess I am at present somewhat sceptical.

But it is not only in a backward direction that the parietal lobe in man has extended its territory. It has likewise increased in a downward direction. There are few points more striking than this in the evolution of the cerebral cortex of man. In order that I may be able to make clear the manner in which this increase has been brought about, it will be necessary for me to enter into some detail in connection with the development of a region of cerebral surface termed the *insular district*. The back part of the frontal lobe is also involved in this downward extension of surface area, and, such being the case, it may be as well to state that the boundary which has been fixed upon as giving the line of separation between the parietal and frontal districts is purely artificial and arbitrary. It is a demarcation which has no morphological significance, whilst from a physiological point of view it is distinctly misleading.

The insular district in the fœtal brain is a depressed area of an elongated triangular form. The general surface of the cerebrum occupies, all round about it, a more elevated plane, and thus the insula comes to be bounded by distinct walls, like the sides of a shallow pit dug out in the ground. The upper wall is formed by the lower margins of the frontal and parietal lobes, the lower wall by the upper margin of the temporal lobe, and the front wall by the frontal lobe. From each of these bounding walls a separate portion of cerebral cortex grows, and these gradually creep over the surface of the insula so as to overlap it, and eventually completely cover it over and exclude it from the surface, in the same way that the lips overlap the teeth and gums. That which grows from above is called the *fronto-parietal operculum*, while that which grows from below is termed the *temporal operculum*. These appear very early, and are responsible for closing over more than the hinder three-fourths of the insula. The lower or temporal operculum is in the first instance more rapid in its growth than the upper or fronto-parietal operculum, and thus it comes about that when their margins meet more of the insula is covered by the former than by the latter. So far the development is apparently precisely similar to what occurs in the ape. The slit or fissure formed by the approximation of the margins of these two opercula is called the Sylvian fissure, and it constitutes a natural lower boundary for the parietal and frontal lobes which lie above it. At first, from the more energetic growth of the lower temporal operculum, this fissure slants very obliquely upwards and backwards, and is very similar in direction to the corresponding fissure in the brain of the ape. But in the human brain this condition is only temporary. Now begins that downward movement of the parietal lobe and back part of the frontal lobe to which reference has been made. The upper or fronto-parietal operculum, in the later stages of fœtal life and the earlier months of infancy, enters into a growth antagonism with the lower or temporal operculum, and in this it proves the victor. The margins of the two opercula are tightly pressed together, and, slowly but surely, the fronto-parietal operculum gains ground, pressing down the temporal operculum, and thus extending the territory of the frontal and parietal districts. This is a striking process in the brain development of man, and it results in a depression of the Sylvian fissure or the lower frontier line of the frontal and parietal lobes. Further, to judge from the oblique direction of the Sylvian fissure in the brain of the ape, the process is peculiar to man; in the simian brain there is no corresponding increase in the area of cerebral cortex under consideration.

I do not think that it is difficult to account for this important expansion of the cerebral surface. In the fore part of the region involved are placed the groups of motor centres which control the muscular movements of the more important parts of the body. These occupy a broad strip of the surface which stretches across the whole depth of the district concerned. Within this are the centres for the arm and hand, for the face, the mouth and the throat, and likewise, to some extent,

the centre for speech. In man certain of these have undoubtedly undergone marked expansion. The skilled movements of the hands, as shown in the use of tools, in writing, and so on, have not been acquired without an increase in the brain mechanism by which these are guided. So important, indeed, is the part played by the human hand as an agent of the mind, and so perfectly is it adjusted with reference to this office, that there are many who think that the first great start which man obtained on the path which has led to his higher development was given by the setting of the upper limb free from the duty of acting as an organ of support and locomotion. It is an old saying 'that man is the wisest of animals because of his hands.' Without endorsing to its full extent this view, I think that it cannot be a matter for surprise that the district of the cerebral cortex in man in which the arm-centres reside shows a manifest increase in its extent.

In the same region of cerebral cortex, but at a lower level, there are also situated the centres which are responsible for facial expression. In the ape there is a considerable degree of facial play; but this is chiefly confined to the region of the lips; and the muscles of the face, although present in greater mass, show comparatively little of the differentiation which is characteristic of the lighter and more feeble muscles in the face of man. And then as to the effect produced: These human muscles are capable of reflecting every fleeting emotion, every change of mind, and by the lines and furrows their constant use indelibly fix on the countenance the character and disposition of an individual can to some extent be read. As the power of communication between primitive men became gradually established, facial movements were no doubt largely used, not only for the purpose of giving expression to simple emotions, such as anger or joy, but also for giving point and force to the faltering speech of our early progenitors by reflecting other conditions of mind. The acquisition of this power as well as the higher and more varied powers of vocalisation must necessarily have been accompanied by an increase of cerebral cortex in the region under consideration. And in this connection it is a point well worthy of note that the area of cortex mapped out in the human brain [1] as controlling the muscles of the face, mouth, and throat is as large, if not larger than that allotted to the arm and hand,[2] and yet it is questionable if all the muscles under the sway of the former would weigh as much as one of the larger muscles (say the triceps) of the arm. This is sufficient to show that it is not muscle power which determines the extent of the motor areas in the cerebral cortex. It is the degree of refinement in the movements required, as well as the degree of variety in muscle combinations, which apparently determines the amount of ground covered by a motor centre.

Still, the increase in the amount of cerebral cortex in man due to the greater refinement of movement acquired by different groups of muscles is relatively small in comparison with the increase which has occurred in other regions from which no motor fibres are sent out, and which therefore have no direct connection with muscles.

The remarkable conclusions arrived at by Flechsig, although not confirmed and accepted in all their details, have tended greatly to clear up much that was obscure in the relations of the different districts of cerebral cortex. More particularly has he been able to apportion out more accurately the different values to be attached to the several areas of the cerebral surface. He has shown that fully two thirds of the cortex in the human brain constitute what he terms 'association centres.' Within these the higher intellectual manifestations of the brain have their origin, and judgment and memory have their seat. They are therefore to be regarded as the psychic centres of the cerebral cortex.

[1] See diagram in Schäfer's article on the 'Cerebral Cortex' in his recent work on physiology.

[2] The comparison only refers to surface area, and this is not an absolutely true criterion of the relative amount of cortex in each region. The arm-centre has a large amount of cortex stowed away within the fissure of Rolando in the shape of interlocking gyri which is not taken into account in a measurement confined to the superficial surface area. Still, this does not to any great degree detract from the argument which follows, seeing that the discrepancy is still sufficiently marked.

Now, it requires a very slight acquaintance with the cerebral surface to perceive that the great and leading peculiarity of the human brain is the wide extent of these higher association centres of Flechsig. Except in connection with new faculties, such as speech, there has been relatively no striking increase in the extent of the motor areas in man as compared with the cortex of the ape or the idiot, but the expansion of the association areas is enormous and the increase in the frontal region and the back part of the parietal region is particularly well marked. It is this parietal extension of surface which is chiefly responsible for the pushing down of the lower frontier of the parietal lobe and the consequent enlargement of its territory.

I have already referred to the views which have been recently urged by several independent observers, that in the men who have been distinguished during life by the possession of exceptional intellectual power, this region has shown a very special development.

It is a curious circumstance, and one which is worthy of consideration, that in the left cerebral hemisphere the Sylvian fissure or the lower boundary of the parietal lobe is more depressed than in the right hemisphere, and, as a result of this, the surface area occupied by the parietal lobe is greater on the left side of the brain than on the right side. To the physiologist it is a matter of every-day knowledge that the left cerebral hemisphere shows in certain directions a marked functional pre-eminence. Through it the movements of the right arm and right side of the body are controlled and regulated. Within it is situated also the active speech centre. This does not imply that there is no speech centre on the right side, but simply that the left cerebral hemisphere has usurped the chief, if not the entire, control of this all-important function, and that from it are sent out the chief part, if not the whole, of the motor incitations which give rise to speech. The significance attached to the dominant power of the left hemisphere receives force from the now well established fact that in left-handed individuals the speech function is also transferred over to the right side of the brain. To account for this functional pre-eminence of the left cerebral hemisphere numerous theories have been elaborated. The interest attached to the subject is very considerable, but it is impossible on the present occasion to do more than indicate in the briefest manner the three views which have apparently had the widest influence in shaping opinion on this question. They are: (1) that the superiority of the left cerebral hemisphere is due to its greater weight and bulk; (2) that it may be accounted for by the greater complexity of the convolutions on the left brain and the fact that these make their appearance earlier on the left side than on the right side; (3) that the explanation lies in the fact that the left side of the brain enjoys greater advantages in regard to its blood supply than the right side.

Not one of these theories when closely looked into is found to possess the smallest degree of value. Braune [1] has shown in the most conclusive manner that if there is any difference in weight between the two hemispheres it is a difference in favour of the right and not of the left hemisphere; and I may add from my own observations that this is evident at all periods of growth and development. Equally untrustworthy are the views that have been put forward as to the superiority of the left hemisphere from the point of view of convolutionary development. I am aware that it is stated that in two or three cases where the brains of left-handed people have been examined this superiority was evident on the right hemisphere. This may have been so; I can only speak for the large percentage of those who are right-handed; and I have never been able to satisfy myself that either in the growing or fully developed brain is there any constant or marked superiority in this respect of the one side over the other; and I can corroborate Ecker [2] in his statement that there is no proof that the convolutions appear earlier on the one side than the other. The theory that an explanation is to be found in a more generous blood supply to the left hemisphere is more difficult to combat,

[1] 'Das Gewichtsverhältniss der rechten zur linken Hirnhälfte beim Menschen,' *Archiv für Anat.*

[2] *Archiv für Anthropologie*, 1868, Bd. cxi.

because the amount of blood received by each side of the brain depends upon two factors, viz., the physical conditions under which the blood-stream is delivered to the two hemispheres and the calibre of the arteries or tubes of supply. Both of these conditions have been stated to be favourable to the left hemisphere. It is a matter of common anatomical knowledge that the supply pipes to the two sides of the brain are laid down somewhat differently, and that the angles of junction, &c., with the main pipe are not quite the same. Further, it is true that the blood-drains which lead away the blood from the brain are somewhat different on the two sides. Whether this would entail any marked difference in the blood-pressure on the two sides I am not prepared to say. This could only be proved experimentally; but, taking all the conditions into consideration, I am not inclined to attach much importance to the argument. It is easy to deal with the loose statements which have been made in regard to the size of leading supply pipe (viz., the internal carotid artery). It passes through a bony canal in the floor of the cranium on its way into the interior of the cranial box. Its size can therefore be accurately gauged by measuring the sectional area of this bony tunnel on each side. This I have done in twenty-three skulls chosen at random, and the result shows that considerable differences in this respect are to be found in different skulls. These discrepancies, however, are sometimes in favour of the one side and at other times in favour of the other side; and when the combined sectional area for all the skulls examined was calculated it was, curiously enough, found to be 583½ sq. mm. for the left side and 583 sq. mm. for the right side.

Leaving out of count the asymmetry in the arrangement of the convolutions in the two hemispheres, which cannot by any amount of ingenuity be twisted into such a form as to give a structural superiority to one side more than the other, the only marked difference which appears to possess any degree of constancy is the increase in the territory of the left parietal lobe produced by the more marked depression of its lower frontier line (Sylvian fissure). That this is in any way associated with right-handedness or with the localisation of the active speech centre in the left hemisphere I am not prepared to urge, because the same condition is present in the ape. It is true that some authorities[1] hold that the ape is right-handed as well as man, but in the gardens of the Royal Zoological Society of Ireland I have had a long and intimate experience of both anthropoid and lower apes, and I have never been able to satisfy myself that they show any decided preference for the use of one arm more than the other.

That differences do exist in the more intimate structural details of the two hemispheres, which give to the left its functional superiority, there cannot be a doubt; but these have still to be discovered. Bastian has stated that the grey cortex on the left side has a higher specific gravity, but this statement has not as yet received corroboration at the hands of other observers.

I have already mentioned that man's special endowment, the faculty of speech, is associated with striking changes in that part of the cerebral surface in which the motor centre for articulate speech is located. It is questionable whether the acquisition of any other system of associated muscular movements has been accompanied by a more evident cortical change. The centre in question is placed in the lower and back part of the frontal lobe. We have seen that the insular district is covered over in the hinder three fourths of its extent by the fronto-parietal and temporal opercula, and thus submerged below the surface and hidden from view. The brain of the ape and also of the microcephalic idiot with defective speech goes no further in its development. The front part of the insular district remains uncovered and exposed to view on the surface of the cerebrum. In man, however, two additional opercula grow out and ultimately cover over the fore part of the insula. These opercula belong to the lower and back part of the frontal lobe, and are to be looked upon as being more or less directly called into evidence in connection with the acquisition of articulate speech.

The active speech centre is placed in the left cerebral hemisphere. We speak

[1] Ogle, 'On Dextral Pre-eminence,' *Trans. Med. Chirurg. Soc.*, 1871; Aimé Père, *Les Courbures latérales normales au rachis humain.* Toulouse, 1900.

from the left side of the brain, and yet when the corresponding region[1] on the right side is examined it is found to go through the same developmental steps.

The stimulus which must have been given to general cerebral growth in the association areas by the gradual acquisition of speech can hardly be exaggerated.

During the whole course of his evolution there is no possession which man has contrived to acquire which has exercised a stronger influence on his higher development than the power of articulate speech. This priceless gift, 'the most human manifestation of humanity'—(Huxley)—was not obtained through the exertions of any one individual or group of individuals. It is the result of a slow process of natural growth, and there is no race, no matter how low, savage, or uncultured, which does not possess the power of communicating its ideas by means of speech. 'If in the present state of the world,' says Charma, 'some philosopher were to wonder how man ever began to build those houses, palaces, and vessels which we see around us, we should answer that these were not the things that man began with. The savage who first tied the branches of shrubs to make himself a shelter was not an architect, and he who first floated on the trunk of a tree was not the creator of navigation.' And so it is with speech. Rude and imperfect in its beginnings, it has gradually been elaborated by the successive generations that have practised it.

The manner in which the faculty of speech originally assumed shape in the early progenitors of man has been much discussed by Philologists and Psychologists, and there is little agreement on the subject. It is obvious that all the more intelligent animals share with man the power of giving expression to certain of the simpler conditions of mind both by vocal sounds and by bodily gestures. These vocal sounds are of the interjectional order, and are expressive of emotions or sensations. Thus the dog is said, as a result of its domestication, to have acquired the power of emitting four or five different tones, each indicative of a special mental condition and each fully understood by its companions. The common barn-door fowl has also been credited with from nine to twelve distinct vocal sounds, each of which is capable of a special interpretation by its fellows or its chickens. The gestures employed by the lower animals may in certain cases be facial, as expressed by the grimaces of a monkey, or changes in bodily attitude, as we see continually in the dog.

I think that it may not be unreasonably inferred that in the distant past the remote progenitors of man relied upon equally lowly means of communicating with their fellows, and that it was from such humble beginnings that speech has been slowly evolved.

There cannot be a doubt that this method of communicating by vocal sounds, facial expression, and bodily gestures is capable of much elaboration; and, further, it is possible, as some hold, that it may have attained a considerable degree of perfection before articulate speech began to take form and gradually replace it. Much of it indeed remains with us to the present day. A shrug of the shoulders may be more eloquent than the most carefully prepared phrase; an appropriate expression of face, accompanied by a suitable ejaculation, may be more withering than a flood of invective. Captain Burton tells us of a tribe of North American Indians whose vocabulary is so scanty that they can hardly carry on a conversation in the dark. This and other facts have led Mr. Tylor, to whom we owe so much in connection with the early history of man, to remark: 'The array of evidence in favour of the existence of tribes whose language is incomplete without the help of gesture-signs, even for things of ordinary import, is very remarkable'; and, further, 'that this constitutes a telling argument in favour of the theory that gesture-language is the original utterance of mankind out of which speech has developed itself more or less fully among different tribes.' It is a significant fact also, as the same author points out, that gesture-language is, to a large extent, the same all the world over.

[1] Rudinger and others have tried on very unsubstantial grounds to prove that there is a difference in this region on the two sides of the brain. There is, of course, as a rule, marked asymmetry; but I do not think that it can be said with truth that the cortical development of the region is greater on the left side than on the right.

Many of the words employed in early speech were undoubtedly formed, in the first instance, through the tendency of man to imitate the natural sounds he heard around him. To these sounds, with various modifications, was assigned a special conventional value, and they were then added to the growing vocabulary. By this means a very decided forward step was taken, and now primitive man became capable of giving utterance to his perceptions by imitative sounds.

Max Müller, although bitterly opposed to the line of thought adopted by the 'Imitative School' of philologists, has expressed their views so well that I am tempted to use the words he employed in explaining what he satirically branded as the 'Bow-wow Theory.' He says: 'It is supposed that man, being yet mute, heard the voices of the birds, dogs, and cows, the roaring of the sea, the rustling of the forest, the murmur of the brook, and the whisper of the breeze. He tried to imitate these sounds, and finding his mimicking cries useful as signs of the object from which they proceeded, he followed up the idea and elaborated language.'

Hood[1] humorously and unconsciously illustrates this doctrine by a verse descriptive of an Englishman, ignorant of French, endeavouring to obtain a meal in France:—

> '"Moo!" I cried for milk;
> If I wanted bread
> My jaws I set agoing;
> And asked for new-laid eggs
> By clapping hands and crowing.'

But, although much of early articulate speech may have arisen by the development of interjectional sounds and the reproduction, by the human vocal organs, of natural sounds, it is very unlikely that these afforded the only sources from which words were originally derived. Romanes insists upon this, and, in support of his argument, refers to cases where children invent a language in which apparently imitative sounds take no part. He likewise alludes to the well-known fact that deaf mutes occasionally devise definite sounds which stand for the names of friends. In the light of such evidence, he very properly asks, 'Why should it be held impossible for primitive man to have done the same?'

The value of spoken language, as an instrument of thought, is universally admitted, and it is a matter incapable of contradiction that the higher intellectual efforts of man would be absolutely impossible were it not for the support which is afforded by articulate speech. Darwin expresses this well when he says: 'A complex train of thought can no more be carried on without the aid of words, whether spoken or silent, than a long calculation without the use of figures or symbols.' Such being the case, I think we may conclude that the acquisition of speech has been a dominant factor in determining the high development of the human brain. Speech and mental activity go hand in hand. The one has reacted on the other. The mental effort required for the coining of a new word has been immediately followed by an increased possibility of further intellectual achievement through the additional range given to the mental powers by the enlarged vocabulary. The two processes, mutually supporting each other and leading to progress in the two directions, have unquestionably yielded the chief stimulus to brain development.

More than one Philologist has insisted that 'language begins where interjection ends.' For my part I would say that the first word uttered expressive of an external object marked a new era in the history of our early progenitors. At this point the simian or brute-like stage in their developmental career came to an end and the human dynasty endowed with all its intellectual possibilities began. This is no new thought. Romanes clearly states that in the absence of articulation he considers it improbable that man would have made much psychological advance upon the anthropoid ape, and in another place he remarks that 'a man-like creature became human by the power of speech.'

The period in the evolution of man at which this important step was taken is

[1] Quoted from *The Origin of Language*, by Hensleigh Wedgwood, 1866.

a vexed question and one in the solution of which we have little solid ground to go upon beyond the material changes produced in the brain and the consideration of the time that these might reasonably be supposed to take in their development.

Darwin was inclined to believe that articulate speech came at an early period in the history of the stem-form of man. Romanes gives a realistic picture of an individual decidedly superior to the anthropoid ape, but distinctly below the existing savages. This hypothetical form, half-simian, half-human, was, according to his sponsor, probably erect; he had arrived at the power of shaping flints as tools, and was a great adept at communicating with his fellows by gesture, vocal tones, and facial grimaces.

With this accomplished ancestor in his mental eye it is not surprising that Romanes was inclined to consider that articulate speech may have come at a later period than is generally supposed.

At the time that Romanes gave expression to these views he was not acquainted with the very marked structural peculiarities which distinguish the human brain in the region of the speech centre. I do not refer to the development of the brain in other districts, because possibly Romanes might have held that the numerous accomplishments of his speechless ancestor might be sufficient to account for this; I merely allude to changes which may reasonably be held to have taken place in direct connection with the gradual acquisition of speech.

These structural characters constitute one of the leading peculiarities of the human cerebral cortex, and are totally absent in the brain of the anthropoid ape and of the speechless microcephalic idiot.

Further, it is significant that in certain anthropoid brains a slight advance in the same direction may occasionally be faintly traced, whilst in certain human brains a distinct backward step is sometimes noticeable. The path which has led to this special development is thus in some measure delineated.

It is certain that these structural additions to the human brain are no recent acquisition by the stem-form of man, but are the result of a slow evolutionary growth—a growth which has been stimulated by the laborious efforts of countless generations to arrive at the perfect co-ordination of all the muscular factors which are called into play in the production of articulate speech.

Assuming that the acquisition of speech has afforded the chief stimulus to the general development of the brain, and thereby giving it a rank high above any other factor which has operated in the evolution of man, it would be wrong to lose sight of the fact that the first step in this upward movement must have been taken by the brain itself. Some cerebral variation—probably trifling and insignificant at the start, and yet pregnant with the most far-reaching possibilities—has in the stem-form of man contributed that condition which has rendered speech possible. This variation, strengthened and fostered by natural selection, has in the end led to the great double result of a large brain with wide and extensive association areas and articulate speech, the two results being brought about by the mutual reaction of the one process upon the other.

The following Papers and Reports were read:—

1. *The Cartilage of the External Ear in the Monotremata in relation to the Human Ear. By* Professor J. CLELAND, *F.R.S.*

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2. *On the Origin of the Cartilage of the Stapes and on its Continuity with the Hyoid Arch. By* J. F. GEMMILL, *M.D.*

The series of sections exhibited showed that in the human subject the whole of the cartilage of the stapes is developed independently of the periotic capsule, and that it belongs to the hyoid bar. The sections also illustrate the condition at different stages of that part of the hyoid bar which lies between the stapes and the styloid process. An examination of all the sections in the different series

supports the view that the incus represents the primitive suspensorial element, *i.e.*, the hyo-mandibular.

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3. The President's Address was delivered.—See p. 776.

4. *Some Notes on the Morphology of Transverse Vertebral Processes. By* Professor A. MACALISTER, *M.D., LL.D., F.R.S.*

The application of this term in the description of the several regions of the human spine is unsatisfactory, and the author has endeavoured to determine, by embryological evidence, the morphological relations of the several parts of the neural arch. The factors which cause the differentiation are the juxtaposition of the rib and the variable relations of the arch to the surrounding muscles.

5. *A Note on the Third Occipital Condyle. By* Professor A. MACALISTER, *M.D., LL.D., F.R.S.*

There are two structures confused under this name—one a mesial ossification in the sheath of the notochord, and the second a lateral, usually paired, form of process, caused by the deficiency of the mesial part of the hypochordal element of the hindmost occipital vertebra, with thickening of the lateral portion of the arch.

6. *Notes on a Human Skull found in Peat in Bed of the River Orwell, Ipswich. By* Miss NINA F. LAYARD.

This skull was obtained in January last from the captain of a dredger employed on the river Orwell at Ipswich. It was found when deepening the channel in May of last year. After working out the overlying mud a bed of peat was reached. This was in such a dry condition that it choked the machinery. As nearly as could be estimated, the skull was found embedded in the peat at a depth of about 4 feet. After being dredged up it was rescued by the captain, and for nine months remained hoisted on a pole in the dredger, exposed to the wind and weather. The skull was very black when first found, but in course of time became bleached. Some oil dropping upon it from the machinery above gave it its present brown appearance. One side of the skull is much worn away by exposure to the air and moisture, while the other side is almost perfect.

In February last the writer presented the skull, which was exhibited, to the Royal College of Surgeons, and Professor Stewart has made the following measurements:—C., 530; L., 188; B., 140; Bi., 745; H., 133; Hi., 707; B.N., 101; Ow., 37; Oh., 29; Oi., 784; Ca., 1,570.

7. *Interim Report of the Committee on Anthropological Teaching.*

8. *Interim Report of the Committee on the Preservation and Registration of Photographs of Anthropological Interest.*

FRIDAY, SEPTEMBER 13.

The following Papers and Reports were read:—

1. *Notes on the Excavation of an ancient Kitchen Midden recently discovered on the St. Ford Links, near Elie, Fife. By* ROBERT MUNRO, *M.D.*[1]

After narrating the circumstances which led to the discovery of the midden, and describing the details of its subsequent excavation by the proprietor, W. Baird, Esq., the author proceeds to give a description of the relics, pointing out their analogy to other Scottish remains, and concludes by briefly stating some of the conclusions suggested by the archæological facts recorded. The points of interest may be thus summarised:—

(1) The midden was composed of a bed of dark earthy matter, about two feet thick, containing ashes, charcoal, decayed bones and horns of various domestic and wild animals, a few sea-shells, and some relics of human occupancy. It lay over a bed of fine sand, within the twenty-five feet raised beach, and at a depth of from two to five feet beneath a grassy mound (formerly a sand-dune). Its shape was oblong, some sixteen paces in length (north to south) by eleven in breadth, and its margins were precisely, sometimes abruptly, defined from the surrounding blown sand.

(2) The chief relics are two ornamental toilet combs (fragmentary), a bone spindle-whorl turned on the lathe, a few bone pens and implements of deer-horn, a curious vessel made from the leg bone of an ox, an eel-spear-head, and a chisel of iron, a small portion of thin bronze, and two fragments of a flat dish of 'false Samian' ware.

(3) From a comparison of these relics with some of those found on the Scottish Crannogs the author dates the midden and its makers, approximately, to the eighth century, and gives reasons for supposing that it was the site of a wooden house.

(4) The presence of an unusually large number of water-worn pebbles which had been subjected to fire, together with the absence of culinary pottery, querns, and hammer-stones, suggest that the occupants were not agriculturists, but pastorals and hunters, who cooked their meat in wooden dishes, boiling water by means of stones previously made red-hot in an open fire.

(5) The osseous remains were very abundant, but greatly decayed. Among the animals represented by them the following were identified by Dr. R. Traquair, F.R.S., viz.—ox (two varieties, one being the longifrons), sheep, pig, horse, fox, dog, red- and roe-deer, three portions of bones of some species of whale, one of which showed the marks of a sharp axe.

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2. *Report on the Excavations of the Roman City at Silchester.* See Reports, p. 425.

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3. *Excavations at Ardoch. By* J. H. CUNNINGHAM, *Sec.S.A.Scot.*

This paper, after a brief description of the earthworks at the Roman station of Ardoch, in Perthshire, gives an account of the excavations which were carried on there in 1896–97 by the Scottish Society of Antiquaries. The following were the chief results obtained in the course of the operations: (1) The structure of the main rampart resembled that of the Antonine 'Wall.' (2) Fragments of charcoal

[1] This paper will be published in the *Proceedings of the Society of Antiquaries for Scotland* (1900-1901).

and pottery were generally found in a layer about thirty inches below the surface, and about the same height above causeway and gravelled surfaces, thus indicating two occupations. (3) From traces of wooden piles systematically placed in rows it was inferred that the structures within the main rampart had been made of wood, and had been laid out on a ground plan similar to that found in other camps. (4) About seventy doubly conical pellets of burnt clay, supposed to have been made red-hot and thrown into the lamp to set fire to the buildings, were collected throughout the site. (5) The relics were on the whole similar to those found on other Roman sites, but the fragments of sculptured or inscribed stones were few and unimportant, and the bulk of the pottery consisted of pieces of large vessels used for kitchen service, fragments of the finer vessels being decidedly scarce. (6) The small mounds, generally known as the 'prætorium,' were shown to belong to a mediæval chapel, probably built not earlier than 1400 A.D. The excavations are fully described in the 'Proceedings of the Society of Antiquaries for Scotland,' vol. xxxii. 1897–98.

4. *Excavations at the Roman Camp at Inchtuthill, in Perthshire. By* Thomas Ross, *M.D., F.S.A.Scot.*

Inchtuthill Roman Camp, Perthshire, is situated on the north bank of the Tay, about six miles down the river from Dunkeld, in the parish of Caputh, the nearest railway station being Murthly.

Inchtuthill is a plateau elevated about 60 feet above the surrounding low-lying fields, which at no distant date were probably covered with water. The Inch is of a triangular shape, about one mile from east to west by about three-quarters of a mile from north to south. About three-fourths of its area is cut off from the camp by a rampart and ditch. The camp, situated in front of Delvine House, is square and occupies an area of fully fifty acres.

It is defended by a single rampart and ditch, and on the south the rampart is double. On the north the defence is the steep bank of 60 feet. Four circular ovens were found in the east ditch.

The *via principalis* leads through the centre of the camp and down to the river on one side, and to the edge of the bank at the other. There is a south gate.

At a distance of about 130 yards eastwards there is a smaller camp overlooking the river, defended on three sides by a rampart and ditch. It extends to about five acres. No gateway or entrance was found.

A destroyed work defending the *via principalis* was found near the river.

In the south-east side of the Inch very complete remains of baths were found, with two brick-built hypocausts and a stokery; one cold-water bath, 12 feet by 7 feet, with steps and lead pipe *in situ*; hot air flue; cement floors, one showing indications of having been tiled; various chambers, with four circular apses.

At the extreme south-west horn of the Inch there is a very strong fort, extending to about three acres, of which space more than one-half is taken up by the defences. These are against the camp, and consist of five parallel rows of ditches and ramparts of uncommon depth and height. This is probably a native work.

The 'finds' consisted of the usual Roman pottery bricks, tiles, lumps of lead, a leaden ring 4½ inches by 3½ inches, one Roman coin, and in the fort a rough sooty stone hearth, &c.

The work connected with the exploration of the camp has been carried out under the direction and care of the Society of Antiquaries of Scotland, and the expense of the undertaking has been generously borne by the Hon. John Abercromby.

Inchtuthill is part of the estate of Delvine, the property of Sir Alexander Muir Mackenzie, Bart., to whom we are greatly indebted for so kindly granting permission to make the excavations, and also for the great personal interest he has taken in the work.

5. *External Circumstances bearing on the Age of Ogham Writing in Ireland.*[1] *By* R. A. S. Macalister.

The question whether Ogham writing is of Christian or Pagan origin is not yet settled. There are, however, some monuments whose situations or special characteristics seem to have a bearing on the problem. Such are the stone at Glenfahan, Co. Kerry, which though itself Christian bears what seems to be a non-Christian occult formula of some sort; certain monuments found associated with tumuli, stone circles, and alignments; and a recently discovered stone at Dromlusk, Co. Kerry, which displays apparently non-Christian symbolism.

6. *Report on Explorations in Crete.*—See Reports, p. 440.

7. *The Neolithic Settlement at Knossos and its Place in the History of Early Ægean Culture.* *By* Arthur J. Evans, *M.A., LL.D., F.R.S.*

The hill of Kephala at Knossos, which contained the remains of the Palace of Minos and early houses going back to the pre-Mycenæan or Kamáres period of Crete, proves to have been the scene of a much earlier and very extensive Neolithic settlement. The exploration of this by the author, in addition to the work on the later remains of the 'Minoan' Palace, has been greatly aided by the grant from the Association in 1900. The remains were contained in a stratum of light clay underlying the later prehistoric buildings, and which seems to have been formed by the disintegration of successive generations of wattle and daub huts and their clay platforms. This clay stratum, which had been a good deal re-used for later foundations, showed a mean thickness on the top of the hill of about five metres. In some places it was over seven metres thick, and went down to a depth of about ten metres below the surface. It contained an abundance of primitive dark hand-made pottery, often punctuated and incised, and with white chalky inlaying, more rarely chrome-coloured. The ornamentation was angular and of textile derivation. Stone implements abounded of greenstone, serpentine, diorite, hæmatite, jadeite, and other materials. Among these were over 300 celts or axes, besides chisels, adzes, hammers, and other implements. The most characteristic implements, however, were the stone maces, the occurrence of which was especially important as bringing the Cretan Stone age into near relation with that of Anatolia—and indeed of Western Asia in general—where, as in the early deposits of Babylonia, stone maces formed a marked feature. This characteristic was shared by pre-dynastic and proto-dynastic Egypt. Another interesting feature among the remains were the small human images of clay and marble which supplied the ancestors and prototypes of the stone images found in the early Metal-age deposits of Crete and the Cyclades.[2] Their Anatolian analogies were pointed out, and reasons were adduced for their ultimate derivation, through intermediate types, from clay figures of a Babylonian Mother-Goddess, such as those lately found in the very ancient deposits at Nippur.

The Neolithic settlement of Knossos was the first settlement of that period yet explored in the Greek world, and in many ways threw an entirely new light on the beginning of civilisation in that area. The contents showed a marked contrast to the earliest Metal-age remains, such as those from the deposit of Hagios Onuphrios in Crete, the date of which was approximately fixed by their association with Egyptian relics and the indigenous copies of them from 2800 to 2200 B.C. There were here no later vase-forms of the high-necked and spouted class, no traces of painted pottery or metal, and no single example of the spiraliform decoration which in the early Metal-age deposits is found fully developed. This negative phenomenon strongly weighed in favour of the view that the Ægean spiral system was introduced

[1] To be published more fully in *Man*, 1902.
[2] Figured in *Man*, 1901, p. 146.

during this later period with other decorative types from the Egypt of the Middle Kingdom, where it had already attained a high development.

The Neolithic stratum of Knossos itself actually underlay later buildings belonging to three distinct prehistoric classes:—

1. The 'Kamáres,' or Early Metal-age Period of Crete, illustrated by the contents of some of the earlier houses. The painted pottery in these was in some cases a mere translation into colour of the incised and punctuated Neolithic designs. This period is approximately dated from the relics found in the Hagios Onuphrios deposit and the Cretan vase fragments found in Egypt in a XIIth Dynasty association from *c.* 2800 to 2200 B.C.

2. The Transitional Period, between the 'Kamáres' age and the Mycenæan. It is probable that the earliest elements of the Palace itself belong to this period, including an Egyptian monument ascribed to the close of the XIIth or Early XIIIth Dynasty, *c.* 2000 B.C.

3. The Mycenæan Period proper, the flourishing epoch of which is approximately fixed by the correspondence of some of the wall paintings with those representing the Keftiu on Egyptian tombs, *c.* 1550 B.C.

Considering the distinct gap in development which still separates the latest elements of the culture represented by the Neolithic stratum of Knossos from the fully developed Kamáres style, it would be rash to bring down the lowest limits of the settlement later than about 3000 B.C. On the other hand, the great depth of the deposit must carry its higher limit back to a very much more remote date. The continued exploration of the Neolithic remains of Knossos is necessary for the full elucidation of many of the problems suggested by these discoveries.

8. *Explorations at Zakro in Eastern Crete. By* D. G. HOGARTH, *M.A.*

The excavation at Zakro in East Crete has been concluded so recently that I must confine myself to a plain statement of the raw material rendered available for study thereby. In estimating the final result it will be necessary to take account of positive and negative evidence, not yet to hand from two other East Cretan sites, lately excavated, Praesos and Gorynia. Zakro lies in the south-eastern angle of the island, and was chosen for research because it falls in the Eteocretan country, anciently reputed to be inhabited by aborigines, and because its safe bay must always have been a main port of call for craft sailing between the Ægean coasts and Africa. The small plain of Zakro, entirely hemmed in by rugged hills, is full of early remains, beginning in the later pre-Mycenæan period and ending with the close of the age of bronze. No implements of iron were found in it at all, and no Hellenic pottery. The town, therefore, owed its existence to a commerce which ceased or passed elsewhere from the Geometric age onward. The earliest settlement was on a rugged spur; and although almost all trace of its structures have disappeared, it has left abundant evidence of itself in the contents of a pit about eighteen feet deep. This was found half-full of broken vases in stone and clay, largely of the singular 'Kamáres' class, not previously found in Eastern Crete. These, however, are mainly of a highly developed technique, and their commonest schemes of ornament reappear unchanged on vases of distinctively 'Mycenæan' fabric. In fact, Kamáres shapes and decoration are more closely related to Mycenæan at Zakro than had been suspected. But the absence of both neolithic antecedents and the earlier kinds of painted ware from this site suggests that its civilisation did not develop on the spot, but was brought by colonists, perhaps partly Cretan, partly foreign. The fine quality of ware in this pit and the fact that, though of various periods, it was apparently all thrown in at one moment leads me to suspect that the pit contained the clearings of an early shrine.

At a later period the settlement extended over a lower spur nearer the sea, and there very massive and large houses were erected and inhabited till the verge of the Geometric period. Their outer walls are Cyclopean, but their inner partitions are of bricks of unusual size. Complete plans were obtained of two of the

largest houses; and parts of several others were explored, including the lower portion of what was probably the residence of the local chief or governor. These yielded a great deal of pottery, ranging from the acme of the Mycenæan period to its close, and the types furnish a better criterion of date than we have possessed hitherto in Crete. Numerous bronze implements were found, but these yield in interest to those from Gorynia. Two tablets in the linear 'Cretan' script show that this system was known, though probably little used, and not indigenous, in East Crete. None were found couched in the pictographic system so often represented on East Cretan gems. Finally a hoard of 500 clay impressions of lost signet gems was brought to light. These display 150 different types and afford a priceless record of Mycenæan glyptic art and religious symbolism. Monstrous combinations of human and bestial forms occur in great variety, half a dozen, which are bull-headed, suggesting varieties of the Minotaur type. The comparison of all this mass of new material with the symbols of Egyptian, Mesopotamian, and other cults, which cannot fail to be fruitful, has yet to be made. Cist burials were discovered in caves farther inland, whose grave furniture seems to support certain negative evidence obtained in the Upper Zakro district and at Praesos, in showing that the aboriginal civilisation of East Crete was independent of both the 'Kamáres' and Mycenæan civilisations. If these last were foreign to the Eteocretan country, it seems improbable that the Eteocretan language, as represented by the Praesos inscriptions, will prove to be that expressed by the linear script on the Knossian tablets; and the hope that these will be deciphered becomes fainter.

9. *Some Results of Recent Excavations in Palestine.* *By* R. A. S. Macalister.

Excavations have been carried out by the Palestine Exploration Fund at Tell Zakariya, Tell es-Sâfi, Tell ej-Judeideh, and Tell Sandahannah, in the west of Judæa, during the last two years. Remains extending over a space of time of some fifteen centuries have been unearthed, divisible into two well-defined pre-Israelite periods, and also the Jewish, Seleucidan, and Roman periods The general result has been to throw considerable light on various questions respecting the civilisation and religion of the inhabitants at different times.

The great caves of Bêt Jibrin and its neighbourhood have also been systematically explored, and some light shed on the problem of their origin and purpose.

SATURDAY, SEPTEMBER 14.

The Section did not meet.

MONDAY, SEPTEMBER 16.

The following Report and Papers were read:—

1. *Report on the Age of Stone Circles.*—See Reports, p. 427.

2. *On the Chronology of the Stone Age of Man, with especial Reference to his Co-existence with an Ice Age.*[1] *By* W. Allen Sturge, *M.D.*

[1] To be published in *Man*, 1902.

3. *Naturally Chipped Flints for Comparison with certain Forms of alleged Artificial Chipping.* *By* G. Coffey.

The author exhibited a series of flints from the Larne raised beach and other beaches on the north coast of Ireland showing the manner in which chipping is effected in the action of the waves. Some of the chipping was quite fresh, probably done by a recent gale, and admirably illustrated the chipping on older flints. He compared the chipping with that on fragments of flint from river-drift gravels at Bedford and with the chipping of the 'Plateaux flints,' and contended that the evidence pointed to the same or a similar cause in both cases.

4. *Prehistoric Man in the Island of Arran.*[1] *By* Eben. Duncan, *M.D.*, *and* Thomas H. Bryce, *M.A.*, *M.D.*

The island of Arran has many sepulchral memorials of its prehistoric inhabitants, but save the stone circles on Manchrie Moor, explored by James Bryce, LL.D., in 1861, none seems to have been examined except by the casual antiquary or reclaiming agriculturist.

In 1896 Dr. Duncan explored a cairn at Torlin, and found a skull, dolichocephalic in its proportions, and a number of bones, but no implements or pottery to fix the age of the interment. On his invitation Dr. Bryce joined him in a more exhaustive examination last summer, after he had obtained the sanction of the factor, J. Auldjo Jameson, Esq., W.S. During the spring and summer of this year by aid of a grant from the Royal Society of Antiquaries of Scotland Dr. Bryce made a considerable series of further explorations. The comparative results of the whole series of investigations may be summed up in the tabular statement annexed.

The table shows that the mere presence of stone implements affords no test of the archæological horizon, but that the pottery found in what have been called 'Megalithic cists serially arranged' clearly distinguishes these structures as of earlier age than the short cists either in cairns or circles, and one may with fair certainty affirm that the interments discovered in them belong to a race still in the stage of Neolithic culture.

Only at Clachaig and Torlin were human bones discovered in such preservation as to permit of examination. At Sliddery and Shiskin all traces of the interment had disappeared, but in spite of a large amount of wood charcoal found, the absence of any trace of burnt bone makes it probable that the interments in these cists also were by inhumation.

Each large cist contained the huddled remains of six to ten individuals of both sexes and all ages, from the infant to the aged person. The bones lay in chaos in the corners at different levels, suggesting either that the bodies were dismembered before burial, or that they were placed in a sitting attitude in the corners so that when the soft parts fell away the bones collapsed in confused heaps.

The long bones recovered were much broken. No male femur is entire, but making allowance for the absent lower end one bone gives a proportionate stature of 5 ft. 4 in. The bones taken to be female are remarkable for their shortness and slenderness. Two entire femora made the stature 4 ft. 10 in. All the male femora are platymeric, and have a prominent luna aspera; all the tibiæ more or less platycnemic.

The skulls—three male, one female—and three calvaria, of doubtful sex, are of the same general type. They are of large capacity, of gently curved contour, with slightly marked glabella and supraciliary ridges. The form is elongated; the sides are flattened, with slightly marked parietal eminences; the occiput is round and prominent to a marked degree; the outline in the norma occipitalis is pentagonal, with elevated sagittal suture and roof fairly sharply sloping to join the vertical sides. In the norma verticalis the zygomatic arches just show, and the shape is either ellipsoidal or ovoid.

[1] To be published in full: the archæological evidence in *Proc. Soc. Ant. Scot.* the anthropometry in *Journ. Anthrop. Inst.*, xxxii.

	Name and Nature of Cairn or Cist	Explorer	Implements of Stone	Implements of Bronze	Ornaments	Pottery	Human Bones
Megalithic Cists serially arranged. Group A.	Torlin—Four compartments.	E. D. and T. H. B.	Flint scraper . . .	—	—	Fragment of thick black clay urn *without ornament*.	Bones in confused heaps belonging to many individuals of both sexes and all ages.
	Clachaig—Two compartments.	E. D. and T. H. B.	Polished stone-axe .	—	—	(*a*) Thick black clay urn *without* ornament. (*b*) Thin hard-baked reddish-clay vessel with round bottom, and ornament of impressed dots and groups of vertical lines.	Same.
	Sliddery—Three compartments.	T. H. B.	Flint scraper; flint arrowhead.	—	—	Thick dark clay urn with largish pebbles in clay. Round bottom *without* ornament.	One fragment of an unburnt femur.
	Shiskin—Three compartments.	"	Polished and perforated stone hammer, three flint scrapers, several flint flakes.	—	—	Fragments of black clay urn *without* ornament.	Fragments of unburnt (?) bone.
Short Cists in Cairns. Group B.	Clachaig—Lime kiln cairn. Secondary interment cist 3·4 × 1·8.	T. H. B.	Flint scraper . . .		—	Large darkish clay globular urn with mouldings and pattern in chevrons. Bottom absent.	Several fragments of unburnt long bones.
	Clachaig — Flagstaff norma. *Two cists.* Primary 3·9 × 1·7 to 2·1. Secondary, 2·7 × 1·7.	"	Flint flake	—	—	Fragments, red clay urn with mouldings. Pattern of chevrons and oblique lines of dots.	—
	Circular cairn 26 ft. in diameter in the Liac-a-bhriac. *Cist* 3·2 × 1·8.	"	—	—	14 jet discs perforated.	Red clay urn. Flat bottom with cross of finger-nail marks, rich ornamented mouldings and pattern in chevrons.	—
	Site of large cairn, Blackwaterfoot. Cist 4·3 × 2·3.	"	—	Leaf-shaped dagger blade with gold band.	...	—	—
	Drumidoon. *Cist* 3·6 × 2·6 to 3.	"	—	—	—	Previous record speaks of an urn. No description. Now empty.	—
Short Cists within Circles. Group C.	Circle No. II. on Plan. Cist A. 3 × 1·10.	Jas. Bryce, LL.D.	Four flint arrowheads .	—	—	Richly ornamented urn with flat bottom and mouldings.	—
	Cist B. ditto	"	. .	Cist empty.	. .	—	—
	Circle No. III. Cist A about same size.	"	Several flint arrowheads .	—	—	Urn of same description as II., Cist A.	—
	Cist B 3 × 1·4	"	Two flint arrowheads . .	—	—	—	Skull and some long bones.
	Circle No. IV. Cist of about same dimensions.	"	Three flint arrowheads .	—	Bronze pin.	Broken urn, character not stated.	Fragments of bones burnt?
	Circle No. V. Cist of about same dimensions.	"	—	Cist had been rifled.	...	—	—

The cephalic indices of the whole specimens are 66·6, 70, 75, and 75·5, so that two belong to the dolichocephalic group, two to the lowest term of the mesaticephalic group; the three calvaria unquestionably belong to the same series.

The face is orthognathous and leptoprosopic in the male, chamæoprosopic in the female skull. The nose is leptorhine in two, mesorhine in two, the orbits microseme in all. The mandible has a well-marked chin and moderately marked angle. The teeth are moderate and much worn on the crowns.

These skulls are in distinct contrast to the specimen discovered by Dr. James Bryce in the stone circle on Manchrie Moor. It is not sufficiently entire for measurement, but to the eye in the norma verticalis the breadth bears a considerably larger proportion to the length than in the skulls discovered by us.

Thus in the 'Megalithic cists serially arranged' in Arran individuals of a race were interred with anatomical characters closely resembling those of the long barrows in England, and two of the specimens exactly realise Wilson's description of a kumbecephalic skull.

5. *The Bones of Hen Nekht.*[1] *By* Charles S. Myers, *M.A.*

Hen Nekht is the earliest king of whom the remains have been found. He reigned over Egypt during the third dynasty, about 4000 B.C. Mr. John Garstang, who discovered the tomb last season, asked me to undertake the measurement and description of the bones. I am indebted to him for permission to give the British Association my results to-day, before they are more fully incorporated in the official report of his excavations, which is to be published by the Egyptian Research Account. The bones recovered are the skull, the tibiæ, a left humerus, left femur, left clavicle, broken fibulæ, pelvis, and scapulæ. The vertebræ and fragments of other bones were not brought away.

The skull is extraordinarily massive and capacious. The cranial length-breadth index is 79·3, the nasal index 51·9, the orbital index 82·2. The face seems orthognathous. The long bones reflect the character of the skull. They are remarkably long and strongly ridged.

The bones are those of an unusually tall man. The coefficients, however, for determining stature from the length of the long bones differ considerably in individuals as well as in races. The height of Hen Nekht may probably be estimated at 1,870 millimetres. Such a stature would very likely have been considered gigantic by the king's historians.

Manetho records as the last two kings of the second dynasty Sesochris and Cheneres, whose reigns amounted to seventy-eight years. Eratosthenes, another historian, after apparently omitting the second dynasty, places Momcheiri, reigning seventy-nine years, as head of the Memphite (third) dynasty. Possibly Sesochris and Cheneres were one and the same king, to whom Eratosthenes gave the name of Momcheiri. Manetho describes Sesochris as *a giant five cubits in height and three palms* [*in breadth*—omitted in one of the texts]. Eratosthenes describes Momcheiri as περισσομελής and as a Memphite. A marked discrepancy occurs in all lists between the close of the second Thinite and the opening of the third or Memphite dynasty. Possibly with the introduction of stone buildings and pyramids, and with the change of the seat of government from This to Memphis, a new ruling race arose at Memphis with the third dynasty, of whose kings, one, tall among his own people, was reckoned a giant by his Egyptian subjects.

Whether or not Hen Nekht, Momcheiri, and Sesochris are identical may be disputed, but there can be little doubt that the stature of the last has been exaggerated by Manetho.

The features of Hen Nekht's skull agree far closer with those of the dynastic than with those of the prehistoric times, according to Mr. Randall-MacIver's measurements.

The proportions borne by the long bones of Hen Nekht to one another and

[1] Published more fully in *Man*, 1901. No. 127.

to his probable stature correspond more nearly with those observed in Negro than in European skeletons. Similar measurements made on a number of skeletons of the prehistoric and early empire period show in most cases the same correspondence. But further research is here necessary.

6. *Palæolithic Implement with alleged Thong-marks. By* Miss NINA F. LAYARD.

This fine Palæolithic hatchet was found in Levington Road, Ipswich, at a depth of about five feet. In the natural depressions of the flint the original surface of the nodule escaped being worked away when the hatchet was shaped, leaving a rough surface. This surface consists of more than one layer, the outermost of which appears to have been removed by friction.

7. *On a Piece of Yew from the Forest Bed on the East Coast of England, apparently cut by Man. By* F. D. LONGE.

This object was found by the author with other pieces of yew in a section of cliff exposed after a high tide in the Kessingland Freshwater Bed, belonging to the Cromer Forest Bed Series. Some days afterwards, in cleaning the piece of yew, he discovered two oblique cuts upon it, made by some implement much sharper and thinner than the large manufactured instruments (Palæolithic or Neolithic) with which we are familiar. He believes that the circumstances exclude the idea that these cuts are of recent origin.

8. *Exhibition of Manufactured Objects from Irish Caves. By* G. COFFEY.

9. *On the Temporary Fissures of the Human Cerebral Hemispheres, with Observations on the Development of the Hippocampal Fissure and Hippocampal Formation. By* Professor J. SYMINGTON, *M.D., Queen's College, Belfast.*

This paper discussed the views recently published by Hochstetter, who maintains that the so-called temporary or transitory fissures of the human cerebral hemispheres, which have been described by so many anatomists as existing towards the end of the third and during the fourth months of fœtal life, are not present in the fresh brain, but are the products of commencing maceration and putrefication. Professor Symington admitted that the frequency of the occurrence and the depth of these fissures had been exaggerated, but he showed a number of photographs of specimens, both macroscopic and microscopic, in support of the view that they did occur in well-preserved material. He admitted, however, that the arcuate fissure, even if not an artificial product, had no morphological significance, and that its posterior part had nothing to do with the hippocampal fissure. He also exhibited a series of sections of the brain of a human fœtus in which the hippocampal fissure and the hippocampal formation could be traced from near the temporal pole of the hemisphere upwards and forwards towards the frontal end of the brain *dorsal* to the developing transverse commissures.

Attention was directed to the interest of these facts in connection with the position of the hippocampal fissure and formation in the marsupialia and monotremata where they occupy a similar position throughout life. These observations also support the opinion, hitherto based mainly on comparative anatomy, that the rudimentary grey and white matter existing on the dorsal aspect of the adult human *corpus callosum* is the remains of a hippocampal formation.

10. *On Supra-sternal Bones in the Human Subject.* *By* Principal MACKAY, *M.D., LL.D.*

11. *The Frequency and Pigmentation Value of Surnames of School Children in East Aberdeenshire.* *By* J. F. TOCHER, *F.I.C., and* J. GRAY, *B.Sc.*

In the course of a pigmentation survey carried out by us in East Aberdeenshire in 1896 and 1897 we obtained the statistics of the surnames and pigmentation of 14,561 (practically the whole) school children there. An analysis of the physical characteristics apart from the surnames has already been published.[1] The present paper deals with the distribution of the frequencies of surnames and their correlation with pigmentation. We have found that among the 14,561 children there are 751 different surnames. The frequency of these surnames varies between 1 and 267, Milne being the most frequent, the next in order being Smith, Taylor, Stephen, and Bruce. If the surnames are arranged in order of frequency a curve representing the frequency takes the form roughly of a rectangular hyperbola. The distribution of surnames is very unequal: for example, one-half of the population has to be content with 12½ per cent. of the surnames, while one-half of the surnames is monopolised by 950 persons. Hereditary surnames were not in common use in Scotland until the thirteenth and fourteenth centuries. There is a presumption, therefore, that the present possessors of surnames inherit some of the physical characteristics of ancestors of that date. It becomes necessary to investigate the origin of surnames. We have divided them broadly into two classes: (1) Lowland, including names of Anglo-Saxon, Norman, and Scandinavian origin; (2) Highland, including names derived from the names of Highland clans. Of the 751 surnames, sixty-three were Highland, representing 13–14 per cent. of the population. It is interesting to note that in a previous investigation[2] we came to the conclusion, from an analysis of the measurements of the adult population, that the Highland element was present to the extent of 14 per cent. in East Aberdeenshire. We have calculated the pigmentation value of the hair and eyes for the fifty-nine most frequent surnames, and arranged them in series according to pigmentation. We find that there is a wide variability in the pigmentation of different surnames, pointing to the conclusion that septs or clans, as represented by surnames, tend to retain distinct physical characteristics. Amongst the darkest in the series we find surnames common in fishing communities. This supports the tradition that the fishing population on the east coast of Scotland is of Belgian origin, since the Belgians are the darkest people of Northern Europe. We find that the pigmentation of Highland surnames corresponds closely with the pigmentation in their districts of origin. An example of this is seen in the blond Frasers, having their origin in the blond Inverness district, and dark Robertsons and Gordons in dark Perthshire and West Aberdeenshire. The surnames of Wallace, Pirie, Grant, Park, and Birnie, we find, have strong blond tendencies, while the surnames of Cordiner, Cruickshank, Stephen, Strachan, Buchan, Paterson, and Whyte are darkest in our list. The surnames having the largest percentage of red hair are Rennie, Scott, Grant, and Thomson, and those having the least percentage are Johnston, Walker, Burnett, Forbes, and Watson.

The validity of these conclusions depends on whether they are confirmed by a complete survey of the whole of Scotland, which, we hope, may be carried out at an early date.

[1] *Journ. Anthrop. Inst.*, vol. xxx. pp. 104–125.
[2] See *Brit. Assoc. Report*, Bradford, 1900.

TUESDAY, SEPTEMBER 17.

The following Papers and Reports were read:—

1. *On the Functions of the Maternal Uncle in Torres Straits.* *By* W. H. R. Rivers, *M.D.*

In the western tribes of Torres Straits descent is at the present time strictly paternal, and yet customs exist among these people which show that in some respects the relationship between maternal uncle and nephew is regarded as nearer than that between father and son. The system of kinship is of the kind known as 'classificatory,' and the customs to be described apply not only to the brothers of the mother, in the strict sense, but to all those males of the clan of the same generation as the mother whom the latter would call brother.

A man will cease fighting at once when told to do so by his maternal uncle. The power of the uncle is so great that a fight between the natives of two hostile islands (Mabuiag and Moa) might be stopped if a man on one side saw his sister's son among his enemies.

This power of stopping a fight is not possessed to the same extent by the father or mother, and a man may continue to fight even after the father or mother has given certain indications of the nearness of the bond between them and the son. The maternal uncle, on the other hand, stops a fight by a mere word.

The brother-in-law (*imi*) has also the power of stopping a fight, but in this case it is the duty of the man who has been stopped to make a present to the brother-in-law. No such present is made to the uncle.

Another indication of the closeness of the relationship between maternal uncle and nephew is that the latter may take, lose, spoil, or destroy anything belonging to his uncle (even a new canoe, probably the most valuable possession a man can have) without a word of reproach from the latter. I was told that, even if the nephew was quite a small boy, he could do what he liked in his uncle's house—could break or spoil any of his uncle's property and the uncle would say nothing.

As a boy grew up he went about more with his uncle than with his father, and I was told that he cared more for his uncle. At the ceremonies connected with the initiation of the boy into manhood, it was the maternal uncles who had especial care and complete control of the boy, and imparted to him the traditions and institutions of the tribe. When the boy married, the father provided the necessary presents; but the actual payment was made by the maternal uncle, to whom the presents were given by the boy's father.

One point of interest in these customs is that they are found in a tribe in which descent is now paternal, and must probably be regarded as vestiges of a previous condition in which descent was maternal, and the brothers of the mother were regarded as nearer kin than the father.

Another point of more special interest is to be found in the similarity between one of these customs and the 'vasu' institution of Fiji. This institution, which has been spoken of as the 'keynote of Fijian despotism,' may be regarded as an extreme development of the custom which in Torres Straits permits a nephew to take anything belonging to his maternal uncle. In Fiji this custom has grown to such an extent that the nephew of a king may be 'vasu' to all his uncle's subjects, and may, with impunity, despoil his uncle's subjects of all their most valued possessions.

2. *On the Functions of the Son-in-Law and Brother-in-Law in Torres Straits.* *By* W. H. R. Rivers, *M.D.*

In both the eastern and western tribes of Torres Straits, as in so many parts of the world, a man is not allowed to utter the names of his wife's relatives. He does not speak to his father-in-law, and carries out any necessary communication

through his wife. If, for any reason, it should become necessary to speak to his father-in-law, he talks in a low voice and mild manner.

In the western tribe this disability is associated with certain duties and privileges. The brother-in-law has the power of stopping a fight, but apparently not to so marked an extent as in the case of the maternal uncle.

When a man dies the duty of looking after the body and the mourners falls largely on the brother-in-law (*imi*). If the man has died away from home it is the duty of the 'imi' to announce the death to the widow and brothers of the deceased, and the 'imi' gives the signal for the crying 'keening' to commence. He prepares the body and carries it to the grave. He stops the crying, gives food to the mourners, and fills the pipe of the brother of the dead man. If no brother-in-law is present these duties devolve on the father-in-law (*ira*), or, if no 'ira' is present, on the sister-in-law (*ngaubat*). Owing, however, to the large number of brothers-in-law provided by the classificatory system of kinship, this rarely happens.

The brother-in-law has also definite duties in connection with fishing, and has a definite place in the fore part of the canoe. It is his duty to hoist the sail, to heave the anchor, to bale out water, to light the fire and prepare food, and to spear the dugong or turtle. He has, in fact, to do all the hard work, while the owner or captain of the boat has little to do beyond giving orders. In special kinds of fishing, as in that in which the sucking fish is used—of which Dr. Haddon has given an account—certain of the operations are carried out by the brother-in-law.

At a dance a man does not wear his own mask (*kra*) but that of his brother-in-law.

It seems probable that these customs may be regarded as vestiges of a condition which does not now exist in Torres Straits, but is found in many parts of the world, viz., a condition in which a man lives with and serves the family of his wife.

These customs, and those connected with the maternal uncle, agree in pointing to the existence, at some time, in Torres Straits of a stage in the development of the family in which the husband was a relatively unimportant appendage, and the head of the family was the brother of the wife; a stage of development which is still to be found in some parts of the world, as among the Seri Indians, recently investigated by McGee.

[The full account of this and the preceding Paper will be published in the *Report of the Cambridge Anthropological Expedition to Torres Straits.*[1]]

3. *Some Emotions in the Murray Islander.* *By* Charles S. Myers.

A belief is widely spread that in the degree of their control over the impulses of their emotions lies the essential difference between the civilised and uncivilised mind, and that the emotions of a savage are accordingly a series of powerful stimuli, directly and automatically releasing their appropriate actions without the effective intrusion of thought, reason, or self-consciousness.

The writer's experiences, as member of Dr. Haddon's Cambridge Anthropological Expedition to the Torres Straits and Borneo, have led him to doubt whether such a view is particularly or even broadly true. He found that the general conduct of the Murray Islanders, an undoubtedly vivacious and excitable people, was comparable to that of other similarly emotional country folk, *e.g.*, the rural population of South Europe. He believes that such differences as exist are due not so much to distinctive mental constitution as to the varying sanctions and customs of society.

The intense excitement prevailing at the games of the Murray Islanders perhaps atoned for their remarkable disregard for orderly competition; a feature which is perhaps to be connected with the feeble fighting powers and the social equality of these people in the past.

[1] See also *Man*, 1901, pp. 136, 137.

Lack of concentration has been generally considered a characteristic of uncivilised races. Probably no conditions are more absorbing than the deeply rooted emotions of love, hatred, anger, and fear. Fear of his neighbour was very common among the Murray Islanders. No human life, no crop of food, was ever lost save through the sorcery practised by some enemy thereon. Extraordinary mental depression, even death, is reported to have followed an islander's belief that some one had used magic against him.

The feeling of shame was awakened under conditions which are astonishing to us. The birth of twins was a matter of great reproach both to the father and to the mother. Shame was likewise excited if a man mentioned the name of any of his wife's relatives.

Just as social custom in Murray Island encouraged the play of shame, so it appears to have lessened the force of parental affection. Infanticide used formerly to prevail. To this day the practice is retained of frequently giving away infants for adoption a few days after birth, so that they grow up ignorant of their true father and mother.

So far as was noticed, the expression of the emotions in no way differed from what has been observed among Europeans.

Certain psychological experiments demonstrated great differences in temperament among the various islanders.

4. *Notes on Some Customs of the Fellahin of West Palestine.* *By* R. A. S. Macalister.

The paper consists of brief notes on tatu, native feasts, marriage ceremonies, and other details in the daily life and customs of the Fellahin.

5. *Report on the Ethnological Survey of Canada.*—See Reports, p. 409.

6. *Dekanawideh, the Law-giver of the Caniengahakas.*[1] *By* John Ojijatekha Brant Sero.

The author, himself a Canadian Mohawk, discusses the significance of the name Iroquois, which he derives from *I-ih* : *rongwe* : 'self' (*i.e.*, 'genuine,' 'real') 'man,' in allusion to the boasted superiority of the Iroquois over their neighbours. He recounts the traditional origin of the ancient system of government still in use among the Six Nations of Canada, and the symbolic form in which it was handed down by its originator, *Dekanawideh*. The purpose of the gens system and of the matriarchal element in the constitution is explained, and their practical workings are described. The paper concludes with an account of the symbolic forms of debate which are observed in the great tribal and grand Council, and with an estimate of the influence of these institutions upon the Mohawk ideals and character.

7. *The Tehuelche Indians of Patagonia.* *By* Hesketh Prichard.

The author describes the anthropological results of the 'Express' Expedition to Patagonia among the Tehuelche Indians, a nomad people living in *toldos*. Their physical characteristics, past history, and curious customs are described, with details of their marriage customs and of the position of women among them. The outlines of their religion are given, and their fear of the cordillera is discussed. A description of the *Galichu* follows. The native methods of hunting, *guanaco*, and of training horses are detailed. The author examines the Tehuelches' ideas of distance, and their attitude towards the white man, and

[1] Published in full in *Man*, 1901, p. 134.

concludes by an account of their relations with the traders. A note is added on the native mode of burial.

8. *The Lengua Indians of the Gran Chaco.* *By* SEYMOUR HAWTREY.

The author describes the country and the distribution of the Lengua Indians—their physical type, language, social organisation, mode of life, industries and religion—and notes the effects of contact with Paraguayan and European civilisation. The paper will be published in full in the 'Journal of the Anthropological Institute,' vol. xxxi.

9. *Report on the Skeat Expedition to the Malay Peninsula.*
See Reports, p. 411.

10. *The Wild Tribes of the Malay Peninsula.*[1] *By* W. W. SKEAT, *M.A.*

1. The Malay Peninsula, its position in S.E. Asia. Distribution of British and Siamese possessions therein.

2. The wild tribes. Martin's classification:—

(*a*) Dark, frizzly-haired Negrito tribes, called Semang, residing in the northern districts.

(*b*) Lighter wavy-haired tribes called Sakai, in southern districts.

(*c*) Mixed tribes in contact with Malay settlements (also in southern districts).

3. Description of Semangs (type *a*) as follows:—

Height of men, about 4 ft. 9 in.; women, about 3½ inches shorter.

Colour of skin, very dark brown, passing into black.

Head, between long and round (mesaticephalic); forehead, low and rounded, projecting over the root of the nose, which is short and very flat or spreading; eyes round, open, bright, and straight (not oblique); iris, rich deep brown; lips moderate and mouth rather large; chin but little developed, and slight prognathism.

Hair very dark brownish-black (never blue-black, as among Malays and Chinese), curling closely to the scalp.

4. Description of Sakais (type *b*) as follows:—

Height does not materially differ from that of the Semangs.

Colour of skin, much lighter than that of the Semangs, with reddish tinge about breast and extremities.

Head, long (dolichocephalic); among the purest Sakai markedly so; eyes restless, not bright, semi-closed. Face inclined to be long, but broad at the cheekbones, with pointed chin; elliptical; forehead flat, but brow often beetling, the notch above the nose being very deep; nose small, often slightly tilted and broad, with deep-set nostrils; beard consisting of a few long frizzly chin-hairs, remarkably like that of the Veddas of Ceylon, to whom, at first sight, the Sakai present considerable resemblance.

Hair, lank and wavy, often worn in a great 'shock.'

5. Specimens of the types referred to above.

6. Food of the wild tribes mainly vegetable (wild roots and fruits), eked out by any sort of animal food procurable.

7. Hunting and trapping. The blowgun and the bow. The former is a long slender tube or blowpipe composed, when possible, of a single joint or internode of bamboo, over six feet long, which, for protection, is inserted in a similar (slightly larger) tube or case. Method of using it. Darts, poisoned with the sap of the upas tree (Antiaris), or the upas creeper (Strychnos), and made to break off in the wound. Range and effect of these darts.

[1] To be published in full in *Journ. Anthrop. Inst.*, vol. xxxii.

8. Clothing of the Wild Tribes.—Cloth manufactured from beaten tree-bark. Methods of wearing this cloth. Girdle manufactured from the rhizomorph of a fungus. Necklaces and magic combs worn in their hair by women as a protection against fever and snake-bite, &c.

9. Huts and shelters of the wild tribes.—The tree-hut, lean-to, beehive-shelter, and palm-leaf hut.

10. Musical instruments, festivals, and songs. The nose-flute. Head-dresses, leaf-festoons and leaf-bouquets, said to be worn to entrap demons.

11. Chiefs and medicine-men. The exorcism of demons. The tiger-man, or *b'lian*.

12. Marriages: the so-called ant-heap ceremony.

13. Burials: the soul-hut erected beside the grave of the deceased.

14. Ideas of a future life: the moon as the Island of Fruits, as Wild Man's Paradise.

11. *Anthropological Notes on Sai Kau, a Siamo-Malayan Village in the State of Nawnchik (Tojan). By* NELSON ANNANDALE, *B.A., and* HERBERT C. ROBINSON.

12. *A Provisional Classification of the Swords of the Sarawak Tribes.*[1] *By* R. SHELFORD, *M.A.*

The short swords or parangs of the Sarawak tribes are divisible into ten principal varieties: The *parang ilang* or *malat* of the Kayans, Kenyahs, Kalabits, Punans, and allied tribes; the *niabor*, *langgai tinggang*, *jimpul*, and *bayu* of the Sea-Dyaks: the *pakayun* of the Muruts; the *parang pedang* of the Malays and Milanos; the *latok* of the Malays and Milanos; the *buko* and the *pandat* of the Land-Dyaks.

The blade of the *parang ilang* or *malat* differs from all others in being concave on the inner side, convex on the outer side; the blade also curves slightly outwards. A zoomorphic pattern is usually present on the outer side of the blade, rarely on the inner side. The back of the blade is shorter than the edge, so that the blade appears as if it had been obliquely truncated: this truncate edge may be termed the 'slope.' The character of the slope varies very considerably, and on these variations the natives base a complicated classification of this type of weapon. The handle is usually of stag's horn: it is very elaborately carved and decorated with tufts of dyed hair. The sheath is composed of two grooved slats of wood (as is also the case in all the other varieties of parangs), tightly bound together with lashings of rattan and decorated with hair; a small bark pocket is lashed to the inner side of the sheath, and contains a small knife.

The *niabor* is the characteristic weapon of the Sea-Dyaks. The blade is strongly curved, and the back and edge pass insensibly to a point, so that there is no slope; there is a prominent finger-guard. The handle is much flattened laterally, and is invariably carved with a phyllomorphic pattern.

The *langgai tinggang* is practically a niabor with the handle of a parang ilang; the term langgai tinggang, meaning the longest tail-feather of a hornbill, is applied to this weapon by reason of a broad groove which runs along the blade on each side, fancifully supposed to be feather-like in appearance.

The *jimpul* is of recent origin, and may be considered as a hybrid between the langgai tinggang and parang ilang. The blade has flat sides, thus resembling the two preceding types of parangs; but the back and edge do not pass insensibly to a point, but there is a short and abrupt slope. An incised phyllomorphic design typically decorates both sides of the blade near its insertion into the handle, but of late years the Sea-Dyaks have taken to copying Kayan and Kenyah zoomorphic designs in the ornamentation of their weapons. The handle is of the parang ilang type.

[1] To be published in full in *Journ. Anthrop. Inst.*, vol. xxxi.

The *bayu* is a double-edged sword; the centre of the blade on each side is grooved and ornamented with an incised pattern.

The *pakayun* is a long, narrow curved blade, which is never ornamented with a design. The handle is invariably made of wood, and is quite characteristic in shape; the grip of the handle is supplied by a cylinder of brass expanding at the insertion of the blade into a circular lip, which serves as a finger-guard.

The *parang pedang* is largely used in agriculture. The blade is long, very strongly curved, and very broad at the end, tapering rapidly to the point of insertion into the handle. The handle is of wood, and of a distinctive shape.

The *latok* is characterised by the open angle which the shoulder of the blade and the handle form with the rest of the blade. The cutting part of the blade is not curved, the back is slightly shorter than the edge, and there is a short curved slope. The back is very thick, so that the blade is wedge-shaped in section; the shoulder is square or polygonal in section. The weapon is held in both hands by the handle and shoulder, and forms a very efficient chopping implement.

The *buko* is similar in shape to the latok, but is a much slighter weapon, and the handle is carved in deep relief with a phyllomorphic pattern, whereas the handle of the latok is not ornamented with carving.

The *pandat* is the war-parang of the Land-Dyaks: it is remarkable in having no handle, the elongated and angled shoulder serving the purpose. A hole passes through the middle of the shoulder, and in this is inserted a short cross-piece of iron. The termination of the blade is cut with a V-shaped notch, forming a re-entering angle; occasionally the limbs of this angle are produced into hooks and projections. The sheath is decorated with tinfoil, on which is hammered geometrical and phyllomorphic designs.

WEDNESDAY, SEPTEMBER 18.

The following Papers were read:—

1. *Personal Identification: A Description of Dr. Alphonse Bertillon's System of Identifying Fugitive Offenders, called by him 'Le Portrait Parlé.' By* WILLIAM M. DOUGLAS, *Superintendent of Police, Glasgow.*

Identification is the basis of all police work, and it is necessary to have a system or systems which will meet the twofold purpose of individualising persons at large as well as persons in custody. Dr. Alphonse Bertillon, chief of the Judicial Identification Service in Paris, has elaborated a system which is divided into three parts, viz., anthropometric signalment, descriptive signalment, and signalment by peculiar marks. The descriptive signalment is the one by which a criminal may be recognised among the multitude of human beings; the anthropometric intervenes to establish his identity and reconstitute his previous criminal history if he is a recidivist; and the peculiar marks serve to place beyond doubt the results obtained by the other two. The groundwork of Bertillon's descriptive system is the selection for description of characteristics which have the most fixity in the individual and the most variability in different people, and the application to the descriptive terms of the method of limits of approximation. The descriptive information is divided into three sections: I. Chromatic characters; II. Morphological characters, having special headings on card; III. Morphological characters without special headings. The first embraces the colour of the eyes, shades of beard and hair and complexion; the second, the forehead, nose, ear, and build; and the third, the lips, chin, contour of head, nature, abundance, and implantation of hair and beard, eyebrows, eyelids, wrinkles, neck, attitude, general demeanour, voice, language, clothing, and social status. For the purpose of describing peculiar marks the body is divided into six sections, on each of which there are datum points to locate the marks, the nature, form, dimension,

and direction of which are noted in addition to localisation. The practicability of the system for police purposes has been tested by the writer, and it has been demonstrated that men of ordinary intelligence can master its apparent intricacies and apply it successfully.

2. *Notes on the Proposed Ethnographic Survey of India.* — *By* W. CROOKE.

3. *Horn and Bone Implements found in Ipswich.* *By* Miss NINA F. LAYARD.

These implements of horn and bone found in Ipswich came from several parts of the town, and from various depths.

Among the cut antlers is one from the bed of the river Orwell, which resembles the horn picks exhibited in the Guildhall Museum.

The rest of the examples shown, though certainly suggestive of a pick, are perhaps too awkward for this use, though in one case the tip has been sharpened.

Ten of these horns (eight of them cut) were found lying together at a depth of 5 to 6 feet in one of the main streets of Ipswich. Among them is a very rude knife-handle.

All the horns already mentioned appear to be of much more recent date than four others which were found in gravel at a depth of 23 feet, of which, however, 12 feet were of made-up earth.

In other parts of the same excavations numerous Romano-British relics were discovered, but at a much higher level, and always in dark earth.

Other implements from the same gravel were exhibited, and also a large antler found with a skeleton beside which lay a portion of a Saxon comb. These were found quite separate from the rest, 4 feet below the surface of the ground.

A pair of bone skates, found in College Street, Ipswich, was also shown below the foundations of some very old houses that were being pulled down, at a depth of 10 feet, in the old river bed.

4. *Hints of Evolution in Tradition.* *By* DAVID MACRITCHIE.

The author quotes the recent discoveries of pithecoid men in Central Africa, and infers from this instance that similar undeveloped types of mankind may have survived in other parts of the world until comparatively recent times. In support of this view he quotes the Welsh tale of *Kilhwch and Olwen*, with its descriptions of arboreal progression and of hairy men. The 'half men' of the same tale he compares with the Scandinavian 'half-trolls' and with the *Halvermannekens* of Flemish tradition. Shakespeare's conception of Caliban he regards as founded upon similar reminiscences, while the mediæval descriptions of 'Ogres' are largely based upon traditions of the 'Ugrian' Huns, with projecting canines and cannibal propensities.

Other instances of simian traits preserved in popular tradition are:—(1) The excessively long arms attributed to the Scandinavian dwarfs and to the Picts of the Scottish Border. (2) The excessive hairiness of the 'satyrs' of classical and Biblical tradition, and of the Northern 'brownies' (*e.g.*, in Isaiah xxxiv. 14 the Heb. *sagnir* = LXX. σάτυρος = Vulg., *pilosus* = A.V. *satyr* (in Isa. xiii. 21 the Bishops' Bible and Rogers have *ape*) = *fenodyree*, 'brownie,' in the Manx-Gaelic version of 1819 = *fiadh-dhuine*, 'wild man,' in other Gaelic versions). Compare the simian place-names *Affenberg*, *Affenthal*, &c. (3) The small stature of many apes and of the African pygmies is paralleled by the Welsh *nar* (= either 'pygmy' or 'ape') and the Gaelic *abhac*, and by the descriptions of the 'brownies' and other 'little people.' (4) The infrahuman stupidity of very low races; by that of the Scottish 'brownie'; by words like Gael. *amadan*, for a 'changeling'; by the English *oaf* (= *elf*, Fr. *aulfe*), and the Old German *ölp* (= *elf*), defined by Grimm as 'an

awkward, silly fellow, one whom the elves have been at'; and by the Gothic *tumbo*, 'giant' = Lat. *stupidus*.

5. *Magic, Religion, and Science.* *By* J. S. STUART GLENNIE.

On Wednesday, September 11, the Committee resolved that the following letter of congratulation be addressed to Professor Rudolf Virchow on the occasion of his eightieth birthday:—[1]

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

The Section of Anthropology to Professor RUDOLF VIRCHOW.

It seldom falls to the lot of one man to establish a position as you have done as a leader in two great branches of Science. Throughout the world you are generally recognised as the founder of Modern Pathology, whilst in the domain of Anthropology your services have been hardly less remarkable. Wherever anthropologists meet together your name is mentioned with the respect and reverence that are due to a great master.

At the present moment the British Association for the Advancement of Science is holding its annual meeting in Glasgow, and the members of the Anthropological Section, aware that you celebrate your eightieth birthday on October 14, desire to convey to you their affectionate greetings, and to express the hope that you may be spared to add yet further to the indebtedness which they owe to you as a worker in the same field.

Signed on behalf of the Committee of the Anthropological Section.

D. J. CUNNINGHAM, *President.*
J. L. MYRES, *Recorder.*

Glasgow, September 11, 1901.

[1] The Address was presented by Lord Lister to Professor Virchow at the Celebration which was held in Berlin on October 14.

SECTION I.—PHYSIOLOGY (including EXPERIMENTAL PATHOLOGY and EXPERIMENTAL PSYCHOLOGY).

PRESIDENT OF THE SECTION—Professor JOHN G. MCKENDRICK, M.D., LL.D., F.R.S.

THURSDAY, SEPTEMBER 12.

The President delivered the following Address:—

WHEN the British Association met in Glasgow twenty-five years ago I had the honour of presiding over Physiology, which was then only a sub-section of Section D. The progress of the science during the quarter of a century has been such as to entitle it to the dignity of a Section of its own, and I feel it to be a great honour to be again put in charge of the subject. While twenty-five years form a considerable portion of the life of a man, from some points of view they constitute only a short period in the life of a science. But just as the growth of an organism does not always proceed at the same rate, so is it with the growth of a science. There are times when the application of new methods or the promulgation of a new theory causes rapid development, and there are other times when progress seems to be slow. But even in these quiet periods there may be steady progress in the accumulation of facts, and in the critical survey of old questions from newer points of view. So far as physiology is concerned, the last quarter of a century has been singularly fruitful, not merely in the gathering in of accurate data by scientific methods of research, but in the way of getting a deeper insight into many of the problems of life. Thus our knowledge of the phenomena of muscular contraction, of the changes in the secreting cell, of the interdependence of organs illustrated by what we now speak of as internal secretion, of the events that occur in the fecundated ovum and in the actively growing cell, of the remarkable processes connected with the activity of an electrical organ, and of the physiological anatomy of the central nervous organs, is very different from what it was twenty-five years ago. Our knowledge is now more accurate, it goes deeper into the subject, and it has more of the character of scientific truth. For a long period the generalisations of physiology were so vague, and apparently so much of the nature of more or less happy guesses, that our brethren the physicists and chemists scarcely admitted the subject into the circle of the sciences. Even now we are sometimes reproached with our inability to give a complete solution of a physiological problem, such as, for example, what happens in a muscle when it contracts; and not long ago physiologists were taunted by the remark that the average duration of a physiological theory was about three years. But this view of the matter can only be entertained by those who know very little about the science. They do not form a just conception of the difficulties that surround all physiological investigation, difficulties far transcending those relating to research in dead matter; nor do they recollect that many of the more common phenomena of dead matter are still inadequately

explained. What, for example, is the real nature of elasticity; what occurs in dissolving a little sugar or common salt in water; what is electrical conductivity? In no domain of science, except in mathematics, is our knowledge absolute; and physiology shares with the other sciences the possession of problems that, if I may use a paradox, seem to be more insoluble the nearer we approach their solution.

The body of one of the higher animals—say that of man—is a highly complex mechanism, consisting of systems of organs, of individual organs, and of tissues. Physiologists have been able to give an explanation of the more obvious phenomena. Thus locomotion, the circulation of the blood, respiration, digestion, the mechanism of the senses, and the general phenomena of the nervous system have all been investigated, and in a general way they are understood. The same statement may be made as to the majority of individual organs. It is when we come to the phenomena in the living tissues that we find ourselves in difficulties. The changes happening in any living cell, let it be a connective tissue corpuscle, or a secreting cell, or a nerve-cell, are still imperfectly understood; and yet it is upon these changes that the phenomena of life depend. This has led the more thoughtful physiologists in recent years back again to the study of the cell and of the simple tissues that are formed from cells. Further, it is now recognised that if we are to give an adequate explanation of the phenomena of life, we should study these, not in the body of one of the lower organisms, as was at one time the fashion, where there is little if any differentiation of function—the whole body of an amœboid organism showing capacities for locomotion, respiration, digestion, &c.—but in the specialised tissue of one of the higher animals. Thus the muscle-cell is specialised for contraction, and varieties of epithelium have highly specialised functions.

But when cells are examined with the highest microscopic powers, and with the aid of the highly elaborated methods of modern histology, we do not seem to have advanced very far towards an explanation of the ultimate phenomena. There is the same feeling in the mind of the physiologist when he attacks the cell from the chemical side. By using large numbers of cellular elements, or by the more modern and fruitful methods of micro-chemistry, he resolves the cell-substance into proteids, carbohydrates, fats, saline matter, and water, with possibly other substances derived from the chemical changes happening in the cell while it was alive; but he obtains little information as to how these proximate constituents, as they are called, are built up into the living substance of the cell. But if we consider the matter it will be evident that the phenomena of life depend on changes occurring in the interactions of particles of matter far too small even to be seen by the microscope. The physicist and the chemist have not been content with the investigation of large masses of dead matter, but to explain many phenomena they have had recourse to the conceptions of molecules and atoms and of the dynamical laws that regulate their movements. Thus the conception of a gas as consisting of molecules having a to-and-fro motion, first advanced by Krönig in 1856 and by Clausius in 1857, has enabled physicists to explain in a satisfactory manner the general phenomena of gases, such as pressure, viscosity, diffusion, &c. In physiology few attempts have been made in this direction, probably because it was felt that data had not been collected in sufficient numbers and with sufficient accuracy to warrant any hypothesis of the molecular structure of living matter, and physiologists have been content with the microscopic and chemical examination of cells, of protoplasm, and of the simpler tissues formed from cells. An exception to this general remark is the well-known hypothesis of Du Bois-Reymond as to the existence in muscle of molecules having certain electrical properties, by which he endeavoured to explain the more obvious electrical phenomena of muscle and nerve. The conception of gemmules by Darwin and of biophors by Weismann are examples also of a hypothetical method of discussing certain vital phenomena.

Of all the properties of living matter assimilation must no doubt be regarded as the most fundamental. On it depend all vital phenomena. Many physiologists have endeavoured to give an explanation of assimilation by comparing it with crystallisation. But the two processes are very different. The crystal grows by

the addition of new molecules to its surface, but the molecules have already been formed in the solution in which the crystal grows. The molecules are not formed by the crystal; they are simply added to it by a physical force. But assimilation is a different phenomenon. Like a crystal, living matter grows in a nutritive medium, but the molecules which cause the growth do not already exist in the medium. The living matter does not increase by the addition of molecules already made, but by the creation and absorption of new molecules. Other physiologists have attempted to explain assimilation by osmotic action. But osmosis is a purely physical phenomenon. When a substance traverses an organic membrane, it does not become a new substance. There is no change in its constitution. While osmotic action must undoubtedly perform an important *rôle* in the phenomena of assimilation, as we see it in all growth, it cannot fully explain it. But if assimilation is an action of a chemical nature, we can suppose that the molecules of the living matter in certain conditions split up and then act on the molecules of the nutritive medium, detaching atomic groups from these molecules and combining with them to form new molecules similar to those of the original living matter, but possibly not absolutely alike.

Physiologists, however, have often endeavoured to find the cause of assimilation in morphological structure, the structure of the living substance and of the cell. But when we inquire into its nature we find it to be essentially, one might almost say exclusively, a chemical phenomenon, and a chemical phenomenon cannot be explained by morphological structure. A chemical phenomenon depends on the molecular structure and affinities of the atoms of matter in which the phenomenon occurs. Assimilation is not determined by the physical or structural character of protoplasm, or of the cell, or any part of it, but on the chemical constitution of living matter, that is to say upon the structure of its molecules. This view of the subject has led some thinkers, and notably Ermano Giglio-Tos of Turin, in a remarkable book entitled 'Les Problèmes de la Vie,' to form the conception of a biomolecule, or living molecule, that is to say the smallest quantity of living matter that can exhibit some of the chemical phenomena of life, such as respiratory exchange, the function of chlorophyll, the starch-forming function, and functions of disassimilation and secretion.

Living matter, when examined by the highest powers, presents some of the characters of an emulsion; that is to say, it is composed of minute particles with fluid matter between them. These minute particles, built up of biomolecules, have been termed by Tos *biomones*. Biomones, in their turn, form biomonads or bioplasm, or molecular or granular protoplasm, and this again forms the cell. It may be said that these terms are only new names for things that have been long recognised, but it subserves clear thinking to decide upon common terms which all may use. The cell theory undoubtedly has served its day, but it is remarkable that as cytology progresses the physiological importance of different parts of the cell seems to diminish, and it is necessary to give to the constitution of living matter a much wider and more general explanation. The conception of a biomone, that is a minute particle, showing the chemical phenomena of life, enables one to understand how vital phenomena may be manifested without, for example, the existence of a nucleus. The granules in protoplasm, or, as Tos terms them, biomonads, are built up of biomones—and one can conceive that the little colony is symbiotic; that is to say that each part is necessary, and each part co-operates with the rest. But when we come to the ultimate analysis, the distinctive character of different kinds of protoplasm, or cytoplasm, or archoplasm, or corpuscles—call the material by any name the most convenient and expressive, depends on the chemical nature of the substance.

These remarks are all in the direction of showing that as research progresses, and as we get a deeper insight, we find that the phenomena of life are never found in structureless matter. It may appear to be morphologically structureless, even to the highest powers, but in a molecular sense it is structural. The progress of histology also points in the same direction. How often, in former years, were we in the habit of describing appearances in tissues as structureless or 'finely molecular,' which we now know, by better methods shows numerous details of

structure! Think of all the phenomena of karyokinesis, of the changes in the chromatin that have been observed in cells, of the fibrous structure of the so-called grey matter of the nerve centres, of the complicated appearances seen in nerve cells, and indeed in almost all cells. Then progress has been made in the investigation of the chemical constitution of cells. The new school of what one may call the micro-chemists—and I need only mention the name of Dr. Maccallum, of Toronto, as an example of a worker in this difficult department of science—seems to me to be worthy of the attention of all the younger physiologists. I have a strong belief that a careful investigation of the chemical constitution of cells and of living matter, conducted by micro-chemical methods, would be of great value, and might throw some light, not only on the nature of living matter, but on the pathological changes in cells on which disease depends. Morphological examination seems to have been carried nearly as far as it can go; and here I would mention the morphological examination of malignant tumours, and what is now needed is the detection of those subtle chemical changes that lie far beyond the province of the microscope.

The conception, however, of the existence in living matter of molecules has not escaped some astute physicists. The subject is discussed with his usual suggestiveness by Clerk Maxwell in the article Atom in the 'Encyclopædia Britannica' in the volume published in 1875, and he places before the physiologist a curious dilemma. After referring to estimates of the diameter of a molecule made by Loschmidt in 1865, by Stoney in 1868, and by Lord Kelvin (then Sir W. Thomson) in 1870, Clerk Maxwell writes:—

'The diameter and the mass of a molecule, as estimated by these methods, are, of course, very small, but by no means infinitely so. About two millions of molecules of hydrogen in a row would occupy a millimetre, and about two hundred million million million of them would weigh a milligramme. These numbers must be considered as exceedingly rough guesses; they must be corrected by more extensive and accurate experiments as science advances; but the main result, which appears to be well established, is that the determination of the mass of a molecule is a legitimate object of scientific research, and that this mass is by no means immeasurably small.

'Loschmidt illustrates these molecular measurements by a comparison with the smallest magnitudes visible by means of a microscope. Nobert, he tells us, can draw 4,000 lines in the breadth of a millimetre. The intervals between these lines can be observed with a good microscope. A cube, whose side is the 4,000th of a millimetre, may be taken as the *minimum visible* for observers of the present day. Such a cube would contain from 60 to 100 million molecules of oxygen or of nitrogen; but since the molecules of organised substances contain on an average about fifty of the more elementary atoms, we may assume that the smallest organised particle visible under the microscope contains about two million molecules of organic matter. At least half of every living organism consists of water, so that the smallest living being visible under the microscope does not contain more than about a million organic molecules. Some exceedingly simple organism may be supposed built up of not more than a million similar molecules. It is impossible, however, to conceive so small a number sufficient to form a being furnished with a whole system of specialised organs.

'Thus molecular science sets us face to face with physiological theories. It forbids the physiologist from imagining that structural details of infinitely small dimensions can furnish an explanation of the infinite variety which exists in the properties and functions of the most minute organisms.

'A microscopic germ is, we know, capable of development into a highly organised animal. Another germ, equally microscopic, becomes when developed an animal of a totally different kind. Do all the differences, infinite in number, which distinguish the one animal from the other arise each from some difference in the structure of the respective germs? Even if we admit this as possible, we shall be called upon by the advocates of pangenesis to admit still greater marvels. For the microscopic germ, according to this theory, is no mere individual but a representative body, containing members collected from every rank of the long-drawn ramification

of the ancestral tree, the number of these members being amply sufficient not only to furnish the hereditary characteristics of every organ of the body and every habit of the animal from birth to death, but also to afford a stock of latent gemmules to be passed on in an inactive state from germ to germ, till at last the ancestral peculiarity which it represents is revived in some remote descendant.

'Some of the exponents of this theory of heredity have attempted to elude the difficulty of placing a whole world of wonders within a body so small and so devoid of visible structure as a germ by using the phrase structureless germs. Now one material system can differ from another only in the configuration and motion which it has at a given instant. To explain differences of function and development of a germ without assuming differences of structure is, therefore, to admit that the properties of a germ are not those of a purely material system.'

The dilemma thus put by Clerk Maxwell is (first) that the germ cannot be structureless, otherwise it could not develop into a future being, with its thousands of characteristics; or (second) if it is structural it is too small to contain a sufficient number of molecules to account for all the characteristics that are transmitted. A third alternative might be suggested, namely, that the germ is not a purely material system, an alternative that is tantamount to abandoning all attempts to solve the problem by the methods of science.

It is interesting to inquire how far the argument of Clerk Maxwell holds good in the light of the knowledge we now possess. First, as regards the *minimum visible*. The smallest particle of matter that can now be seen with the powerful objectives and compensating eyepieces of the present day is between the $\frac{1}{400000}$ and the $\frac{1}{500000}$ of an inch, or $\frac{1}{20000}$ of a millimetre in diameter, that is to say, five times smaller than the estimate of Helmholtz of $\frac{1}{4000}$ of a millimetre. The diffraction of light in the microscope forbids the possibility of seeing still smaller objects, and when we are informed by the physicists that the thickness of an atom or molecule of the substances investigated is not much less than a millionth of a millimetre, we see how far short the limits of visibility fall of the ultimate structure of matter.

Suppose, then, we can see with the highest powers of the microscope a minute particle having a diameter of $\frac{1}{20000}$ of a millimetre, it is possible to conceive that some of the phenomena of vitality may be exhibited by a body even of such small dimensions. Some of the objects now studied by the bacteriologist are probably of this minute size, and it is possible that some may be so small that they can never be seen. It has been observed that certain fluids derived from the culture of micro-organisms may be filtered through special filters, so that no particles are seen with the highest powers, and yet those fluids have properties that cannot be explained by supposing that they contain toxic substances in solution, but rather by the assumption that they contain a greater or less number of organic particles so small as to be microscopically invisible.[1]

[1] The evidence upon this point is derived from pathological sources. I am indebted to my friend Dr. James Ritchie, of the Pathological Institute of Oxford, for the following notes:

Notes on Organisms too small to be seen by the Microscope.

The filters used in the work performed in the investigation of such organisms are of several kinds and patterns. They are tubes or solid cylinders made of either (*a*) kieselguhr as in the Berkefeld filter, or (*b*) of unglazed porcelain as in the Chamberland and Kitasato filters. They are of varying degrees of porosity according to the fineness of the material used. The most porous, *i.e.*, those which will let through the largest particles, are the Berkefeld; next comes the Chamberland 'F' pattern; next the Chamberland 'B' pattern and the Kitasato tubes. All such filters are used either by forcing the liquid through by pressure or by inserting them into a filter flask which can be exhausted. The finer kinds will keep back all known bacteria. Further, as showing their mode of action, the finer kinds will not allow all the constituents of such a fluid as blood serum to pass through; a certain amount of albumen is kept back. The three diseases which have been investigated

The evidence is briefly as follows: micro-organisms produce chemical substances or toxines which have certain physiological effects; these toxines cannot increase without the presence of micro-organisms; if, then, the micro-organisms

in which there appears to be evidence of the presence of organisms too small to be seen by the microscope are foot-and-mouth disease, the contagious pleuro-pneumonia of cattle, and South African horse-sickness.

(1) *Foot-and-mouth Disease.*—Loeffler and Frosch[1] have shown that the lymph from the vesicles in the mouth of an infected animal if filtered through a Berkefeld filter still in a dose of $\frac{1}{30}$ c.c. killed a calf in the same time as the unfiltered lymph. This experiment was controlled as to the impermeability of the filter by infecting the lymph before filtration by a culture of a very minute bacterium which did not pass through the filter. The highest microscopic power failed to detect anything in the filtrate. They found, however, that if the lymph were mixed with a fluid more rich in albumen than the lymph itself, then the filtrate lost its infectiveness.

(2) *Pleuro-pneumonia.*—Nocard[2] found that the pleural effusion mixed with water if filtered through a Berkefeld or a Chamberland 'F' was still infective, but in such watery fluids it was arrested by the Chamberland 'B' and by the Kitasato. He further found that there were in the infective filtrate refractile particles, which, however, could not be resolved by a magnification of 2,000 diameters, but which he considered might be the infective agents.

(3) *Horse-sickness.*—McFadyean[3] found that the diluted blood of an infected horse could pass through a Berkefeld and through a Chamberland 'F' and still remain infective; and, further, that if the blood of a horse which had died from this infection were filtered through a Chamberland 'B' it was still infective and killed a horse in the same time as the original filtrate. Again microscopically nothing could be seen, and again the efficacy of the filters was controlled by mixing the blood to be tested with putrefactive organisms which the filter kept back as usual. Nocard[1] in one case says that blood can be freed of this infection by filtration, but McFadyean's experiments are very numerous and so carefully done that this one negative instance may be explained by want of susceptibility in the animal used.

Of course the great difficulty is to be sure that the filters were efficient and had no cracks, which such filters are very apt to have, but the work has been so carefully controlled that this source of error may be excluded. The remaining source of objection is that the pathogenic agent might not be a bacterium but its toxine. The most important experiments here are those of McFadyean, who filtered the blood of horses infected with filtered blood and found it still infective; and also those of Loeffler, who goes carefully into this question and finds that such an explanation is not feasible. The formation of fresh toxine within an animal's body, apart from the actual presence of the bacteria which ordinarily form it, is unknown, and McFadyean's work—where with the second horse's blood the period of fatal illness was practically the same as with similar quantities of the filtrate from the first horse—I think, clinches the matter.

Excerpt from a Letter from Dr. Ritchie.

The only objection to the validity of the experiments I think is that it might be a toxine that passes through. I briefly stated [in above notes] an answer to this objection, namely, McFadyean's work, when he inoculated a second horse from the filtered blood of a horse that had itself been infected with filtered blood. Now it might be urged even against this experiment that such a large quantity of poison had been injected into the first horse that even when it had been diluted by all the body fluids of that horse, and had been diminished by excretion for the eight or ten days of the first horse's life, there still remained a large quantity, and it was part of this that killed the second horse. Now if this were the case, there evidently must have been much less given to the second horse than to the first; and if this were so, the duration of the fatal illness in the second horse would have been much longer. Now this latter did not occur. They both died in about the same time. In fact so different were the doses given in McFadyean's different experiments that if it were a toxine

[1] *Centralblatt f. Bakter.*, xxiii. 371.
[2] *Bulletin de la Société Centrale de Méd. Vétérinaire* (N.S.), xvii. 441.
[3] *Journ. Comparative Path.*, xiii. 1; xiv. 103.
[1] *Recueil de Méd. Vétérinaire*, ser. viii., tome viii. 37.

are removed by filtration, and if the toxine solution is very much diluted, the solution when injected into a living animal should produce a weaker effect than when the unfiltered fluid is introduced. This, however, is not the case. The filtered fluid, in which no micro-organisms can be seen with the highest powers, after some time, acts as virulently and rapidly as an unfiltered fluid, and the inference is justifiable that invisible micro-organisms are still present, as without these it is difficult to account for the persistence of virulence. I am of opinion, therefore, that it is quite justifiable to assume that vitality may be associated with such small particles, and that we have by no means reached what may be called the vital unit when we examine either the most minute cell or even the smallest particle of protoplasm that can be seen. This supposition may ultimately be of service in the framing of a theory of vital action.

Weismann in his ingenious speculations has imagined such a vital unit to which he gives the name of a biophor, and he has even attempted numerical estimates. Before giving his figures let us look at the matter in another way. Take the average diameter of a molecule as the millionth of a millimetre, and the smallest particle visible as the $\frac{1}{20000}$ of a millimetre. Imagine this small particle to be in the form of a cube. Then there would be in the side of the cube, in a row, fifty such molecules, or in the cube $50 \times 50 \times 50 = 125{,}000$ molecules. But a molecule of organised matter contains about fifty elementary atoms. So that the 125,000 molecules in groups of about fifty would number $\frac{125000}{50} = 2{,}500$ organic particles. Suppose, as was done by Clerk Maxwell, one half to be water; there would remain 1,250 organic particles. The smallest particle that can be seen by the microscope may thus contain as many as 1,250 molecules of such a substance as a proteid.

Weismann's estimates as to the dimensions of the vital unit to which he gives the name of biophor may be shortly stated. He takes the diameter of a molecule at $\frac{1}{2000000}$ of a millimetre (instead of the one millionth) and he assumes that the biophor contains 1,000 molecules. Suppose the biophor to be cubical, it would contain ten in a row, or $10 \times 10 \times 10 = 1{,}000$. Then the diameter of the biophor would be the sum of ten molecules, or $\frac{1}{2000000} \times 10 = \frac{10}{2000000}$ or $\frac{1}{200000}$ of a millimetre. Two hundred biophors would therefore measure $\frac{200}{200000}$ or $\frac{1}{1000}$ mm. or 1 μ (micron = $\frac{1}{1000}$ mm.). Thus a cube one side of which was 1 μ would contain $200 \times 200 \times 200 = 8{,}000{,}000$ biophors. A human red blood corpuscle measures about 7·7 μ; suppose it to be cubed, it would contain as many as 3,652,264,000 biophors. If the biophor had a diameter of $\frac{1}{100000000}$ mm. the number would be much smaller.

Now if the smallest particle that can be seen ($\frac{1}{20000}$ mm.) may contain 1,250 molecules, let us consider how many exist in a biophor, which we may imagine as a little cube, each side of which is $\frac{1}{200000}$ mm. There would then be five in a row of such molecules, or in the cube $5 \times 5 \times 5 = 125$ molecules; and if the half consisted of water about sixty molecules.

Let us apply these figures to the minute particles of matter connected with the hereditary transmission of qualities. The diameter of the germinal vesicle of the ovum is $\frac{1}{20}$ of a millimetre. Imagine this a little cube. Taking the diameter of an atom at $\frac{1}{10000000}$ of a millimetre, and assuming that about fifty exist in each *organic molecule (proteid, &c.), the cube would contain at least 25,000,000,000,000 organic molecules.* Again, the head of the spermatozoid, which is all that is needed for the fecundation of an ovum, has a diameter of about $\frac{1}{200}$ mm. Imagine it to be cubed; it would then contain 25,000,000,000 organic molecules. When the two are fused together, as in fecundation, the ovum starts on its life with over 25,000,000,000,000 organic molecules. If we assume that one half consists of water, then we may say that the fecundated ovum may contain as many as about

that he was using the periods of fatal illness ought to have varied, which they did not do very much. Taking everything into account, while infection by a toxine cannot be absolutely excluded, still in the cases of foot-and-mouth disease and horse-sickness the experiments I think strongly indicate that it is actually some form of life which passes through the filter.

12,000,000,000,000 organic molecules. The organic molecules we are considering are such as build up living matter, namely, proteids, fats, carbohydrates, saline substances, and water. There is, however, no satisfactory evidence that they exist as such in living matter, and it may be that they are formed when living matter dies. Thus the molecule of living matter may be a much more complicated molecule than even that of such a complex proteid as hæmoglobin, so that it may contain 10,000 atoms. But even if this were the case the fecundated ovum might yet contain 1,200,000,000 of such complex molecules. Clerk Maxwell's argument that there were too few organic molecules in an ovum to account for the transmission of hereditary peculiarities does not apparently hold good. Instead of the number of organic molecules in the germinal vesicle of an ovum numbering something like a million, the fecundated ovum probably contains millions of millions. Thus the imagination can conceive of complicated arrangements of these molecules suitable for the development of all the parts of a highly complicated organism, and a sufficient number, in my opinion, to satisfy all the demands of a theory of heredity. Such a thing as a structureless germ cannot exist. Each germ must contain peculiarities of structure sufficient to account for the evolution of the new being, and the germ must therefore be considered as a material system.

Further, the conception of the physicist is that molecules are more or less in a state of movement, and the most advanced thinkers are striving towards a kinetic theory of molecules and of atoms of solid matter which will be as fruitful as the kinetic theory of gases. The ultimate elements of bodies are not freely movable each by itself; the elements are bound together by mutual forces, so that atoms are combined to form molecules. Thus there may be two kinds of motion, atomic and molecular. By molecular motion is meant 'the translatory motion of the centroid of the atoms that form the molecule, while as atomic motion we count all the motions which the atoms can individually execute without breaking up the molecule. Atomic motion includes, therefore, not only the oscillations that take place within the molecule, but also the rotation of the atoms about the centroid of the molecule.' [1]

Thus it is conceivable that certain vital activities may be determined by the motion that takes place in the molecules of what we speak of as living matter. It may be different from some of the motions known to physicists, and it is conceivable that in the state we call living there may be the transmission to dead matter, the molecules of which have already a kind of motion, of a form of motion *sui generis*. The imagination fails to follow the possible movements of molecules in a particle of living protoplasm. We cannot grasp the wondrous spectacle of the starry heavens with its myriads of orbs all in motion, each motion being rigorously determined. But if we could see into the structure of living matter, we would find another universe of molecules in movement, and here again we would also find the rigor of law. On the character and complexity of these movements will depend the physical and chemical phenomena manifested by this living matter. The chemical irritability of living matter which is perhaps one of its most remarkable characteristics, the rapid series of chemical exchanges going on between its own parts and between itself and the matter surrounding it, the changes in surface tension, in elasticity, and the changes in electrical condition, are all in some way associated with the movements of the molecules of which it is constructed. It will only be when we have grasped the significance of these molecular movements that we will be able to give a rational explanation of the ultimate phenomena of the living state. Just as the physicists of to-day are striving towards a dynamical conception of the phenomena of dead matter, so I believe the physiologists of to-morrow (a far off to-morrow) will be striving towards a dynamical conception of life founded on a molecular physiology.

I offer these remarks with much diffidence, and I am well aware that much that I have said may be regarded as purely speculative. They may, however, stimulate thought, and if they do so they will have served a good purpose. Meyer writes as follows in the introduction to his great work on 'The Kinetic Theory of

[1] Meyer, *Kinetic Theory of Gases*. Translated by Baynes, London, 1899, p. 6.

Gases,' p. 4:—'It would, however, be a considerable restriction of investigation to follow out only those laws of nature which have a general application and are free from hypothesis; for mathematical physics has won most of its successes in the opposite way, namely, by starting from an unproved and unprovable, but probable, hypothesis, analytically following out its consequences in every direction; and determining its value by comparison of these conclusions with the result of experiment.'

The following Papers were read:—

1. *On the Use of the Telephone for investigating the Rhythmic Phenomena in Muscle.* *By* Sir JOHN BURDON SANDERSON, Bart., *F.R.S.*

2. *An Experiment on the 'Motor' Cortex of the Monkey.* *By* Professor C. S. SHERRINGTON, *F.R.S.*

3. *Arsenical Pigmentation.* *By* Professor J. A. WANKLYN, *M.R.C.S.*

The publication of Bunsen's splendid researches on 'A New Series of Organic Compounds containing Nitrogen as a Constituent' was prefaced by a very remarkable pronouncement in 'Poggendorff's Annalen' in the year 1837. The curious liquid known as Cadet's fuming liquor, and discovered in 1760, had for many years been mentioned in the then current chemical literature, and in accordance with the views then prevalent among chemists was looked upon as a compound of acetic acid with arsenic. Bunsen's researches had completely set aside that view of the constitution of the liquid, and in bringing his results before the chemical world Bunsen announced that the compounds of arsenic resembled the compounds of nitrogen rather than the compounds of the common metals. Carbon, hydrogen, oxygen, and nitrogen had been called the organic elements. Bunsen hinted that arsenic belonged to the organic elements, and maintained that oxide of kakodyl (which exists in Cadet's fuming liquor) and kakodylic acid (which is obtained by oxidising Cadet's fuming liquor) are organic compounds in which arsenic has been substituted for nitrogen.

The utmost diversity prevails among organic compounds containing nitrogen: some are virulently poisonous and others are harmless; some are colourless and others are dye-stuffs; and a like diversity is found in the compounds of arsenic.

On the present occasion I wish to call attention to an organic arsenical compound, which is a red pigment discovered by Bunsen about sixty years ago, and named 'Erytrarsin.' According to Bunsen's analysis, its composition is expressed in the formula $C_4H_{12}As_6O_3$.

It is described by Bunsen as being very difficult to obtain, being one of the oxidation products of kakodyl; but the conditions under which it is produced are so little understood that from 100 grammes of oxide of kakodyl the yield of erytrarsin was only half a gramme. Apparently, however, it would seem that traces of it are frequently, and perhaps always, formed during the preparation of kakodyl.

In a recent preparation of kakodyl in an unusual manner in my laboratory I have obtained it, and if I am not deceived the yield is not quite so small as when kakodyl is produced in the usual way. The solid hydride of arsenic is said to be a pink solid. Arsenical films, as is well known, vary greatly in tints: they may be black or various shades of brown, and even yellow. Under certain circumstances it would seem that arsenic enters into combination with carbon and forms a black substance. There is also the well-known yellow sulphuret. In fine, arsenic and its compounds afford abundant scope for great variety of coloration in cases of arsenical pigmentation.

Kakodyl (which is a compound of carbon, hydrogen, and arsenic) is a liquid

which possesses the property of being spontaneously inflammable. At the time of its discovery in 1837 kakodyl afforded the only known example of a liquid which *at once* burst into flame on exposure to the air. The gas phosphoretted hydrogen (which takes fire spontaneously) was known to chemists, and the solid phosphorus was also known. Since the discovery of kakodyl a crowd of spontaneously inflammable substances have come to light. Twelve years later on—1848–1849—the singular substances zinc methyl and zinc ethyl were discovered in Bunsen's laboratory by the late Sir Edward Frankland; and after another ten years (also in Bunsen's laboratory) Wanklyn added to the list potassium ethyl, sodium ethyl, lithium ethyl, calcium ethyl, and strontium ethyl.

Spontaneous inflammability implies that the substance exerts chemical action *energetically* and *with facility.*

Kakodyl of the year 1837 fired spontaneously, and also combined at once with sulphur, chlorine, bromine, and iodine. But kakodyl did not decompose water. Zinc ethyl (1847–48) not only combined with all the elements just mentioned, but it was powerful enough to decompose water instantaneously.

Sodium ethyl (1857–58) displayed energy enough to decompose carbonic acid itself instantaneously, and at ordinary temperatures.

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4. *The Physical Properties of Caseinogen Salts in Solution. By* W. A. OSBORNE, *D.Sc.*

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5. *Colour Vision. By* F. W. EDRIDGE-GREEN, *M.D., F.R.C.S.*

The hypothesis which I have brought forward for discussion at this meeting is that light falling upon the retina liberates the visual purple from the rods and a photograph is formed. The decomposition of the visual purple by light chemically stimulates the ends of the cones and a visual impulse is set up, which is conveyed through the optic nerve fibres to the brain. I assume that the visual impulses caused by the different rays of light differ in character just as the rays of light differ in wave length. Then in the impulse itself we have the physiological basis of light, and in the quality of the impulse the physiological basis of colour. I have assumed that the quality of the impulse is perceived by a special perceptive centre within the power of perceiving differences possessed by that centre or portions of that centre.

FRIDAY, SEPTEMBER 13.

The following Papers were read:—

1. *A Demonstration of Apparatus employed in Researches on the Subject of Phonetics. By* Professor J. G. MCKENDRICK, *F.R.S.*

2. *Restoration of Voluntary Movement after Alteration of the Nerve-supply by Nerve-crossing, or Anastomosis. By* R. KENNEDY, *M.D.*

SATURDAY, SEPTEMBER 14.

The Section did not meet.

MONDAY, SEPTEMBER 16.

The following Papers were read:—

1. *Note on the Action of Oxalates upon the Relationship of Calcium Salts to Muscle. By* W. BRODIE BRODIE, *M.B.*

2. *Can Solutions of Native Proteids exert Osmotic Pressure? By* Professor E. WAYMOUTH REID, *F.R.S.*

3. *An Ionic Effect in the Small Intestine. By* Professor E. WAYMOUTH REID, *F.R.S.*

4. *Has the Spleen a Hæmopoietic Function? By* D. NOEL PATON, LOVELL GULLAND, L. J. S. FOWLER.

5. *The Measurement of Visual Illusion. By* Dr. W. H. R. RIVERS.

TUESDAY, SEPTEMBER 17.

The following Papers were read:—

1. *Observations with Galton's Whistle. By* C. S. MYERS.

2. *Demonstration of a Model showing the Mechanism of the Frog's Tongue. By* Professor MARCUS HARTOG.

The following Reports were received by the Committee:—

1. *Report on the Micro-chemistry of Cells.*—See Reports, p. 445.

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2. *Interim Report on the Physiological Effects of Peptone.*

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3. *The Chemistry of Bone Marrow.*—See Reports, p. 447.

SECTION K.—BOTANY.

PRESIDENT OF THE SECTION.—Professor I. BAYLEY BALFOUR, D.Sc., F.R.S.

THURSDAY, SEPTEMBER 19.

The President delivered the following Address:—

I SHOULD be wanting in my duty, alike to you and to our science, were I at the outset of our proceedings to pass over without notice the circumstances of environment in which we assemble to-day. In this, the first year of the century, our Section meets for the first time in Scotland, and finds itself housed in this magnificent Botanical Institute, which, through the energy and devotion of Professor Bower, has been added this year to the equipment of Botany in this country. A few months ago the Institute was opened in the happiest auspices and with all the distinction that the presence of our veteran botanist, Sir Joseph Hooker, supported by two other ex-Presidents of the Royal Society—Lord Lister and Lord Kelvin—could give to the ceremony. I am sure we will cordially echo the words of good-will that were spoken on that occasion. It must be to all of us a matter of congratulation that Botany has now provided for it in Glasgow this Institute both for its teaching and for the investigation of its inner secrets, and we may with confidence hope that the output of valuable additions to our knowledge of plant-life which has marked Glasgow during the tenure of office of its present distinguished Professor of Botany, and in which he himself has borne so large a share, will not only continue but will increase in a ratio not incommensurate with the facilities that are now provided.

The subject of my address is the group of Angiosperms. I will speak generally of some points in their construction from the point of view of their position as the dominant vegetation of the earth's surface at the present time, and more particularly of their relationship to water, as it is one which has much to do with their holding the position they now have. I wish, however, in the first place to refer to

The Communal Organisation of Angiosperms.

No fact of the construction of the plant-body that has been established within recent years is of greater importance than that of the continuity of protoplasm in pluricellular plants. As has been the case with so many epoch-making discoveries, we owe our first knowledge of this to the work of a British botanist. The demonstration by Gardiner of the existence of intercellular protoplasmic connections is the foundation of our modern notion of the constitution of the pluricellular plant-body and of the far-reaching conception of the communal organisation of Angiosperms and of all other Metaphyta.[1] It has settled, once and for all,

[1] Metaphyta and its antonym Protophyta are well-established names for groups of polyergic and monergic plants respectively. The recent appropriation of Metaphyta as a group name for Vasculares, *i.e.*, plants derived from the second antithetic generation, and of Protophyta for Cellulares, *i.e.*, plants derived from the first antithetic generation, is unfortunate.

phytomeric hypotheses. We now realise that in an Angiosperm the living plurinucleated protoplasm is spread over a skeletal support furnished by the cell-chambers of shoot and root. The energid of each living cell is connected with the adjacent energids by the protoplasmic threads piercing the separating cell-membrane. The protoplasm thus forms a continuous whole in the plant. According to their position in the organism the energids become devoted to the formation of special tissues for the building up of the various organs. Each one of them, however, whilst its actual destiny is ultimately determined by its relationships to the others, is, so long as its fate as a permanent element is not fixed, a potential protophyte, that is to say, it has within it all the capacities of the plant-organism to which it belongs.

Their construction out of this assemblage of protophytes—this colonial, or perhaps better communal, organisation—gives to Angiosperms their power of discarding effete and old parts of the plant-body without mutilation, of allowing these to pass out of the region of active life yet to remain without damage to the organism as part of the body, of renewing and replacing members as required. The response of the plant to the various horticultural operations of pruning, propagation by cuttings, and so forth is an outcome of this constitution. It is this which gives them the power of developing reproductive organs at any part of the plant-body, to cast them off when their work is done, and to renew them again and again. This dispersion of the reproductive capacity in the Angiosperm is one of the most striking of the properties it possesses, and is perhaps in no way better shown than in the development of stool-shoots. There the energids of the cambium, which normally produce the permanent tissue of wood and bark, and thereby add periodically to the girth of a tree, give origin when the relationships are changed by the cutting over of its bole to a callus from which stool-shoots arise as new growths, which may ultimately produce flower and reproductive organs.

Another outcome of this organisation of the Angiosperm is its power of extension and its longevity. It is potentially immortal. How far this expectation of life of a plant is realised in nature we have no evidence to show. Possibly we may presage the longest life in the case of perennial herbs. Trees and shrubs by their exposure in the air are liable to injury which must militate against long life, and yet cases of trees of great age are well known to you all.

It is this feature of the life of Angiosperms which marks them out sharply in contrast with the higher members of the animal kingdom. There we have individuality, and consequently comparatively short life. Let me emphasise this.

Of the Vegetable Kingdom and the Animal Kingdom.

The root-difference between plants and animals is one of nutrition. Plants are autotrophic, animals heterotrophic.

Whatever has been the origin of the two kingdoms, we must trace the differentiation of plants to their acquisition of chlorophyll as a medium for the absorption of the energy of the sun. The imprint of its operation is borne in the construction of all higher plants and distinguishes them from animals. The vegetative mechanism of the plant has been elaborated upon lines enabling it to obtain the materials of its food from gases and liquids which it absorbs from its environment. For the plant the primary requisite has been a sufficient surface of exposure in the medium whence it could obtain energy along with the gases and liquids of its food. To this end the fixed habit is an obvious advantage, for the question of bulk within the limits of nutrition becomes thereby not a matter of moment; and an upward and a downward extension gives opportunity for the creation of a larger expanse of absorptive surface. Thus it has come about that the plant-organism has developed that polarity which finds expression in the profuse root-system and shoot-system with their localised growing points of the highest forms of to-day. That the communal organisation is well fitted to this mode of life requires no exposition.

The nutritive mechanism of animals, on the other hand, has become one for

the ingestion of solids which it obtains by preying upon the bodies of plants and other animals. The exigencies of its feeding have compelled the adoption by the animal of the habit of locomotion, the development of an apparatus for the capture of its prey, and of an alimentary canal for its introduction to the body, for its digestion, and for the final ejection of the unused matter along with the waste of the body. This has involved the concentration and the specialisation of the individual.

All this is, however, to you botanists but the commonplace of your laboratories and lecture halls. But I have thought that it should be said, because this fundamental difference of organisation between the two kingdoms is apt to be forgotten in discussions of problems of evolution, more particularly those of transmission of characters and the effect of environment. This is especially so when they are approached from the zoological side. Were the point always recognised we should not have zoologists finding similarity between bud-variation in a flowering plant and the change in colour of the hair of a mammal.

Of Origin and Dominance of the Angiospermous Type.

It is now usually admitted that all plants, like all animals, have been derived from aquatic ancestors, and that the trend of evolution has been in the direction of the establishment of a vegetation adapted to a life on land. Of this evolution the Angiosperms as we see them to-day are the highest expression. Can we say anything about the origin of the angiospermous type? As the problem presents itself to me we can only mark time at present.

From the geological record we obtain no help. The earliest traces of Angiosperms in rocks of the middle Mesozoic period enable us to say little regarding them except that the fragments give evidence of an organisation as complete as that possessed by the Angiosperms of the present day. The gap between the angiospermous and other types of vegetation is a wide one, and no links are known. Until further research provides specimens in a better state of preservation and showing structure we can hope for little assistance from the geological record; and when we consider the circumstances in which the angiospermous plants as a whole grow the prospect of such finds does not appear to be very bright.

The appeal to ontogeny likewise gives us little information. Comparative study does not establish connection with, only differentiates more and more, the types of the Pteridophytes and Gymnosperms. The strong likeness of the pro-embryo after the primary segmentation of many Angiosperms to the pro-embryo of many Bryophytes has appeared a sufficient reason to some botanists for ascribing a bryophytous parentage to the Angiosperms. Indeed it has been said that 'the monocotylous embryo is the direct homologue of the sporogonium of the moss, the cotyledon being homologous with the spore-producing portion of this out of which it originated.' This anaphytic conception of the monocotylous embryo seems to me to have as little real foundation as the hypothesis of its origin. The pro-embryonic resemblance is interesting, but it may as well be homoplastic as genetic.

But if the information available to us does not permit of our building up a pedigree for the Angiosperms, we are on surer ground when we endeavour to fix upon characters which have enabled the group to become established as the dominant vegetation of our epoch. Before the era at which we have first knowledge of Angiosperms the earth's surface was, we know, clad with a dense vegetation composed of members of the various classes of Pteridophytes and Gymnosperms. These appear to have existed in all the growth-forms which we know now amongst the Angiosperms—Herb, Shrub, Tree, Liane. Yet they are now represented amongst living plants by only a few remanent forms. Hordes of distinct forms and whole classes have disappeared, giving place to plants of the angiospermous type. There must then be some feature or features of advantage in this type over those of the groups that previously occupied the ground, and through which it became dominant.

In considering this point we must bear in mind the well-known climatic differences—particularly in the distribution of water—that distinguishes our epoch

from those in which these extinct plants throve. The factors which determine the success or otherwise of an organism or group of organisms at any period must always be complex, and no exception can be claimed for plants in their struggle for mastery. But looking at the succession of plant-life in the world in relation to the known diminution of water-surface and increase of land-area, and the consequent differentiation of climates, we cannot but be convinced that of these factors water is one which has had supreme influence upon the evolution of the facies of the plant-life that we see to-day. I think the statement is warranted that the Angiosperms have become dominant in great measure because in their construction the problem of the plant's relationship to water on a land-area has been solved more satisfactorily than in the case of the groups that preceded them.

The seed-character—and the flower which it involves—distinguishes the Angiosperms. What, then, are the relationships to water which the formation of seed implies and through which the Angiosperm has advantage?

Two prominent risks in its relation to water attach to the process of sexual reproduction in a plant of the type of heterosporous Pteridophytes. Firstly, that of failure of moisture on the soil sufficient to promote germination of the spores; secondly, that of failure of moisture on the soil sufficient for the passage of the spermatozoid to the ovum. In addition there is the risk of failure of the fall of microspores and megaspores together upon the soil. In the Angiosperms such risks are practically abolished in the formation of flower. The stigmatic surface of the style itself provides a secretion—the more copious in a dry and sunny atmosphere—to moisten the pollen-grain and stimulate germination, and for the spontaneous movement of the spermatozoid is substituted the passive carriage of the male gamete to the ovum by the agency of the pollen-tube. Possible failure of pollination is, too, provided against by the complex mechanism of the flower in the highest forms in relation to insect-visits. The sexual act, then, might, we conceive, gradually become more and more difficult of consummation to the Pteridophyte as the area of dry land increased. To the seed-plant it was more secure by its independence of the presence of free water. The failure of performance of the function of sexual reproduction may have hastened the disappearance of Pteridophytes before the advance of the Angiosperms.

But if this flower-mechanism relieves the Angiosperm from risks in the performance of the sexual act, it imposes a new duty upon the plant, that of nursing the embryo within the sporangium. This involves a water-supply of a kind not demanded in the Pteridophytes, and we may gain some idea of the importance of this by a comparison of the trivial vascular system required to supply through the stamen the pollen-grain, with the copious system that traverses the gynæceum for the ovules. It is, however, to the ovule—the immediate nursery of the embryo—that we must look for special indications of this water-relationship of which I speak.

Perhaps no organ has given rise to more discussion than this characteristic one of flowering plants. To most of us I believe the controversy over its axial or foliar nature will be, in a measure, historical only. All recent investigations of sporangia—and to no one does Botany owe more in this respect than to Bower—tend to confirm the view that it is, and always has been, an organ *sui generis*. To that category the nucellus of the ovule is now pretty generally admitted. It is the body of a sporangium. But the nature of the tegumentary system and of the funicle which give the ovule so distinctive a character is still the subject of disagreement.[1]

I do not share a view which sees in the integuments or other parts of the ovule anything of an axial or of a foliar nature. To me the funicle is a sporangiophore—

[1] Scott's discovery of a bracteal investment to the megasporangium in Lepidocarpon is an interesting one in relation to the question of the enclosure of sporangia. It shows how in the Lepidodendreæ a covering of the sporangium could be developed, much in the same way as a carpellary envelope in Angiosperms. Whether the ovular integument or the ovarian covering in Angiosperms was the earlier development is open to discussion. I am disposed to give precedence to the ovular coat.

a sporangial stalk—and the tegumentary system is an outgrowth of the sporangial primordium of somewhat variable origin and development, whose first function it is to carry and store water for the embryo, and then also to serve as a food-reservoir. The whole construction is adapted to the function claimed for it. The well-developed vascular system from the placenta traverses the funicle, but the subsequent fate of the nucellus forbids its passing through this, and the needs in respect of water (and what it carries) of the embryo and of the other further developments that proceed in the embryo-sac are provided for by the production of the tegumentary outgrowths into which the vascular system may, if necessary, be continued and spread out.

That the tegumentary covering has this function we have direct proof in its penetration by haustoria, derived either from the embryo itself or from the embryo-sac, which absorb from it water and food for the developing embryo. These haustoria appear to be much more elaborate and more widespread than has been supposed, and a definite correlation has been established in many cases between them and the integuments. The thicker the integument the better developed is the haustorium. In some ovules where no vascular system appears in the integument, the chalazal haustorium is prominent, and it can therefore at once tap the main water-supply of the ovule. We know also of cellular ingrowths proceeding from the vicinity of the vascular system of the raphe to the interior of the embryo-sac, and these, too, may have a conducting function. All these point to a water and nutritive function in the integuments. The protective function of the tegumentary system to which attention has been chiefly directed must be primarily only slight. It only becomes prominent as the seed is formed, and then changes consonant therewith, and with its changed function, proceed within it. Nor can we now, with our increased knowledge of the ways in which the pollen-tube may reach the embryo-sac, consider the function of the integuments in forming the micropylar canal as one of so much importance to the reproductive act as was formerly supposed. We obtain, I think, a better conception of the ovule in the view that the primary function of the tegumentary system is that of a water-jacket and food-store, and that it has been developed in response to the special demands for water involved in the seed-habit.[1]

To the question why there are two integuments in some cases and only one in others we can only reply that our knowledge of ovular structure and changes is yet too slight to permit of a definite opinion being expressed. We find that there is a remarkable concurrence of the unitegminous ovule with a gamopetalous corolla in the flower, for the character apparently holds for the whole of the gamopetalous Dicotyledones excepting Primulales. On the other hand, not all Polypetalæ have bitegminous ovules, whilst bitegmeny is usual in Monocotyledones. Recently the character has been used by Van Tieghem as one of prominence in his new classification of the families of Dicotyledones. But it is not so constant an one as his groups of Unitegmineæ and Bitegmineæ would lead one to suppose. The degree in which it is inconstant we cannot yet fix, because we know details of so few genera. We do know, however, that all genera in one family are not always alike in respect of it. In Ranunculaceæ, for instance, the most of the genera with radial flowers are unitegminous, whilst those with dorsiventral flowers are bitegminous. Again, in Rosaceæ, the Potentillæ are unitegminous, as is Rosa, whilst Pomeæ and Pruneæ are bitegminous; and of the Spiræeæ, Neillia is unitegminous, but the closely allied Spiræa is bitegminous.[2] In other cases the

[1] To discuss the morphological interpretations of the funicle and integument that have been advanced would carry me beyond the scope of this address. I do not know that an axial hypothesis for any part of the ovule is now maintained. The foliar interpretation of the funicle and integuments as against their sporangial nature is supported by two distinct schools of botanists. One approaches the subject from the standpoint of the anaphytose of the earlier years of last century, and appeals largely to teratology; the other from that of vascular anatomy. I do not accept the starting-point of either the one or the other.

[2] Spiræa is, however, exalbuminous, whilst Neillia is albuminous.

character confirms distinctions; as, for instance, in separating the unitegminous Betuleæ and Coryleæ from the bitegminous Quercineæ. The explanation of all these constructions may, I suggest, be sought for with better prospect of success in the water-relationship and food-relationship of the integuments to the embryo than in protective function and relations to pollination. It is, perhaps, not without significance from this point of view that in, for instance, the Gamopetalæ such protective function as attaches to the tegumentary system in the seed is reduced or extinguished through the development of indehiscent fruits, accompanied in many Aggregatæ and higher Heteromeræ by the sinking of the gynæceum in the torus, and in many Bicarpelletæ by its enclosure in a persistent accrescent calyx.

All the information at our disposal seems to indicate that the tegumentary system of the ovule is extremely adaptive, and that its characters are not of themselves of much phyletic import. An extended examination of its characters as an organ of the nature I have depicted in relation to embryogeny is greatly needed. It is made all the more interesting by the questions of development of endosperm opened by the discovery of 'double fertilisation.' There is no more promising field of investigation than this, for it must yield results infinitely more interesting than the technicalities of formal morphology which have been for too long the stimulus to ovular research. I am tempted to go further and to say that it might supply an explanation of that most puzzling of subjects, the forms and curvature of the ovule. The common assumption that these have relation to pollination and make the advent of the pollen-tube at the micropyle easier is not altogether satisfactory. For the curvature not infrequently seems to place the micropyle in a position the opposite of favourable, and there is an absence of curvature in cases where it would appear to be desirable.

I will not dwell upon the subject of the seed itself as an advantage to the Angiosperm. Its construction follows upon the successful water-relation previously secured. We all know how its manifold adaptations to dissemination bring about its fortuitous deposition upon various soils, and the embryo is placed well guarded within the seed-coat ready to take advantage of the moment when moisture is sufficient for its germination.

Whilst the seed-habit is the character which has primarily given to Angiosperms their advantage as a land-type,[1] their vegetative organs also show an advance in their relationship to water upon those of the forms they have supplanted. I have already remarked that the growth-forms of the vegetation of the present day are the same as those of old. That means that the early as well as the later groups of vegetation have solved in much the same way, so far as general form is concerned, the problem of the exposure in the atmosphere of a large assimilating area with a sufficient mechanical support and adequate water-supply. That wherever a water-carrying system is found in these growth-forms it dominates the anatomy is witness to the importance of the water-relationships I wish to emphasise.

There are two features in the water-carrying system of Angiosperms in which they are superior to the older types—namely, their general monostely and their vasa.

No one will contest that polystely is a less perfect mechanism for water-carriage in a massive plant than is monostely. The limitation imposed by it to an increment in the area of carriage contrasts unfavourably with the openness in this respect possessed by monostely. In the moister climatic conditions of the age of domination of Pteridophytes polystely may have well sufficed for the water-needs of the plants, especially of the dwarfer forms; but even then, as we know, monostely was the habit in many of the larger tree-forms, and the development of a

[1] Gymnosperms, sharing with Angiosperms the seed-habit, have in that had advantage over Pteridophytes. But their flower-mechanism is much less perfect. The reasons for their being bested as a class by Angiosperms must be complex. Gymnosperms, as a whole as we know them, are less adaptive than Angiosperms. The decadence of the cycadean line of descent may have been helped by their conservatism in the methods of water-carriage in the vegetative organs. The coniferous type has held its own in the Northern Hemisphere.

cambium enabled them to provide for continued additions to their carrying system. Where such monostely and secondary growth occurred in these older types their adaptation in these respects to water-carriage was on lines similar to those of our dominant Dicotyledones and was effective in giving them dominance in their epoch. There is no more interesting page in the history of evolution than that—and we owe it in large measure to the labours of Scott and Seward—upon which is depicted the struggle of some polystelic forms amongst these old plants to achieve the structural facilities more easily attained through monostelic construction. The existence of polystely in a few Angiosperms only confirms the advantage which the whole group has derived from its monostely. Such polystelic forms amongst them as we know have many of them special water-adaptations, and in no case can they be said to be progressive types.

I do not need to remind you that vasa are not the exclusive possession of the angiospermous type, but they are the conspicuous feature of their carrying system, whilst the tracheid is the leading one in the older type of vegetation. All anatomical evidence indicates that vasa give greater facility to rapid transport of water than do other elements, and we may, therefore, conclude that they have been adjuvants in enabling the Angiosperm to meet effectively the demand made upon it by the drier atmospheric conditions.

I now pass on to consider from the same standpoint the classes which make up the group of Angiosperms.

Of the Classes of Angiosperms.

There has been for long a general recognition of two classes amongst the Angiosperms—Dicotyledones and Monocotyledones—separated one from the other by definitive characters which I need not specially depict here. Recently, however, we have seen an attempt made by Van Tieghem to establish another class—that of Liorhizal Dicotyledones—for which is claimed a rank equal to that of the Dicotyledones and Monocotyledones. Were this valid it would be a matter of supreme importance, for whatever be the relationship between Dicotyledones and Monocotyledones there can be no doubt of their having developed as distinct groups within the whole period of which we have knowledge of them, and the existence of a third class intermediate or outside of them might lead to interesting conclusions. It is worth while, therefore, to consider the evidence on which this class is founded. It includes two of our recognised families—the Nymphæaceæ and the Gramineæ.

What is the exact position and the affinities of the Nymphæaceæ amongst Angiosperms is no new theme of discussion. That they have characters resembling those of Monocotyledones[1] has been often insisted on. Van Tieghem lays stress on what he considers the monocotylous differentiation of the root-apex and the derivation of the piliferous layer from the same meristem-initials as the cortex, whilst in the embryo he finds the two cotyledons of Dicotyledones. But the most recent observations of the embryogeny of the family go to show that the embryo is that of the monocotylous plants, the apparent dicotylous character being the result of the splitting of one cotyledon. If this be so the position of Nymphæaceæ will be amongst the Monocotyledones, a position the root-characters in Van Tieghem's view will support. But whether this be confirmed by further research or no—and a complete reinvestigation of their embryogeny and development is much wanted—what we may say at present is that it is not in features such as this one of the root-apex—which is, after all, not so simple and uniform as Van Tieghem would have it—that we are likely to find phyletic diagnostic characters of groups.

The reason for the inclusion of the Gramineæ in this new group is the assumed presence of a second cotyledon. The construction of the embryo of grasses is peculiar, as is well known, and has for a long time been a main support of the

[1] The anatomical characters upon which this resemblance was chiefly based are now known to be of another nature.

hypothesis that the Monocotyledones are derived from the Dicotyledones; for here alone, since the dicotylous character of forms like the Dioscoreæ was shown to be untenable, was there a structure which could be interpreted as evidence of a reduced second cotyledon. The idea that the epiblast is such a structure was enunciated by Poiteau at the beginning of the last century, and along with hypotheses of the nature of the other parts of the grass-embryo has been a subject of vigorous discussion since that time. The controversy is not yet closed. Whilst we have Van Tieghem now adopting the view of the cotylar nature of the epiblast and using it as a character of fundamental taxonomic importance, we have others who as strongly uphold the interpretation of it, first formulated by Gaertner, as a winged appendage of the scutellum, which is considered to be the cotylar lamella. And, again, there are those who take the view that it is a mere outgrowth of the hypocotylar body of the embryo and without any cotylar homology. Our interpretation of the part must depend primarily upon the standpoint from which we view the embryo of Angiosperms. This I shall discuss presently. All I need say here, *à propos* of the class of Liorhizal Dicotyledones, is that whatever the epiblast be—and for my part I am disposed to regard this simple cellular structure as merely an outgrowth with a water-function from the embryonal corm—a dispassionate consideration must lead us to hold that it is a bold step to use a character the morphological value of which can be so variously interpreted as one of primary importance for separation of a group of Angiosperms. Moreover, we must remember that the feature of the epiblast is not one of universal occurrence in the Gramineæ. If we take a well-defined tribe like the Hordeæ, as framed by Bentham and Hooker, we find that of eight of its twelve genera which have been examined for this feature five have the epiblast and three want it. And surely the fact of its presence in Triticum and absence in Secale, its presence in Elymus and absence in Hordeum, is strong evidence that the epiblast is not a character of such importance as it would have were it a reduced cotyledon as is asserted.

It appears to me, therefore, that this third class of Angiosperms has no sound foundation, no more, perhaps less, than Dictyogens and Rhizogens which appeared as parallel groups with Endogens and Exogens in Lindley's old classification. Our present knowledge allows the recognition of only two classes of the angiospermous type—the Dicotyledones and the Monocotyledones.

Of Dicotyledones and Monocotyledones.

The relationship of these two groups is involved in the origin of the angiospermous type. They may have had a common origin or they may have arisen separately; and if the former the Dicotyledones may have been a subsequent offshoot from the Monocotyledones, or the reverse may have been the case. Each of these possibilities has its supporters. Were I to maintain an opinion it would be that the two classes have arisen on separate lines of descent. The embryo-characters, as well as those of the epicotyl, can, I think, be shown to be fundamentally different and to afford no basis for an assumed phyletic connection. The difference between Hepaticæ and Musci, to take a parallel case in a lower grade, are not more conspicuous. The parallel sequence in development in the two classes are no more than one would expect, and may be regarded as homoplastic. To the question which group is the older I would answer that the Dicotyledones are by far the most adaptive and progressive if—as is not necessarily the case—this can be taken as evidence of their more recent origin. This, however, is not the matter I intend to discuss here. I wish rather to inquire if there are any features broadly characterising the groups to which, as in the case of Angiosperms as a whole, we may look for help to an explanation of the predominance at this time of the type of Dicotyledones. I think there are, but they are not to be found in the reproductive system. That is constructed on sufficiently similar lines in each class. The features I refer to are to be found in the construction of the vegetative system both in the embryo and in the adult. That of the former gives the dicotylous plant an advantage in its start on life;

that of the latter, both in shoot-system and root-system, is better adapted in Dicotyledones in relation to water-supply.

I specially differentiate the embryo-condition from the adult because in our consideration of these higher plants we are apt to overlook the two distinct stages into which their life is divided, and which call for altogether different adaptations. There is, firstly, the life in the seed and in germination; and secondly, there is the life after germination. The conditions and the manner of life are not alike in the two stages. In the first the plant is heterotrophic, in the second it is autotrophic. The functions of the portion of the plant which lives the life within the seed, and which bears the incipient epicotyl and primary root as small, at times hardly developed, parts, are to absorb food, either before germination, as in exalbuminous seeds, or during germination in albuminous seeds, to rupture the seed-coat, and to place the plumular bud and the primary root in a satisfactory position for their growth and subsequent elongation. The functions of the adult may be summarised as the development and maintenance of a large assimilating and absorbing area preparatory to reproduction.

We ought, I think, to look upon the embryo as a protocorm [1] of embryonic tissue adapted to a seed-life. Under the influence of its heterotrophic nutrition and seed-environment it may develop organs not represented in the adult plant as we see in, for instance, the embryonal intraovular and extraovular haustoria it often possesses. There is no reason to assume that there must be homologies between the protocorm and the adult outside an axial part with its polarity. There may be homologous organs. But neither in ontogeny nor in phylogeny is there sufficient evidence to show that the parts of the embryo are a reduction of those of the adult.[2]

The protocorm has, I believe, developed along different lines in the Dicotyledones and Monocotyledones. This has been to the advantage of the former in the provision that has been made for rapid as opposed to sluggish further development. Confining ourselves to the general case, the axial portion of the protocorm of the Dicotyledon, the hypocotyl, bears a pair of lateral outgrowths, the cotyledons, and terminates in the plumular bud and in the primary root respectively. The cotyledons are its suctorial organs, and the hypocotyl does the work of rupturing the seed and placing the plumular bud and root by a rapid elongation [3] which commonly brings the plumular bud above ground, protected, it may be, by the cotyledons. These latter may then become the first assimilating organs unlike or like to the epicotylar leaves. In the Monocotyledones the axial portion of the protocorm has usually no suctorial outgrowths. Its apex and usually its base also are of limited growth. The plumular bud is a lateral development, and the primary root often an internal one. The suctorial function is performed by the apex of the protocorm, termed here also the

[1] The term has already been used for the embryo of Orchideæ, where the axis is tuberous as is the structure to which the term has been given in Lycopodineæ. But tuberousness is not an essential for the designation corm.

[2] I cannot pursue the subject here, nor discuss the view of the cotyledons as either ancestral leaf-forms or arrested epicotylar leaves. The analogies with existing Pteridophytes that are cited are not pertinent, for there is no evidence that Angiosperms have that ancestry, or indeed that their phylogeny was through forms with free embryos. Nor is the fact of resemblance between cotyledons and epicotylar leaves and the existence of transitions between them convincing. That the cotyledons, primarily suctorial organs, should change their function and become leaf-like under the new conditions after germination is no more peculiar than that the hypocotyl should take the form of an epicotylar internode, from which it is intrinsically different as the frequent development upon it of hypocotylar buds throughout its extent shows.

[3] In relation to this function it is noteworthy that the hypocotyl relatively seldom in the exalbuminous seed of Dicotyledones becomes the reservoir of food-material, whereas in Monocotyledones the axis of the embryo is the usual seat of deposition.

cotyledon.[1] The rupture of the seed and the placing of the plumule along with the primary root—for the axis of the corm does not elongate between them—are the work of the base of the suctorial portion of the corm.

The whole arrangement in Monocotyledones is in marked contrast with that of the Dicotyledones. Instead of the free axial elongation begun in the protocorm and continued upwards and downwards in the epicotyl and primary root, there is limited axial growth of the protocorm with lateral outgrowth of the plumular bud and arrest of the primary root. These differences in the protocorm are, I think, primary, and they point to independent origins of the two groups. The advantage lies, as I have said, with the Dicotyledones, and we find that the features of development of the protocorm are continued in the adult. There is a marked contrast between the free internodal growth of the shoots of Dicotyledones with their copious root-system and the contracted stem-growth and the arrested root-system in Monocotyledones. It is interesting to note further how the monocotylous type has developed so largely upon restricted lines in the way of short rhizomatous, often tuberous, growth, whilst the dicotylous gives us the characteristic growth-form tree.

When we compare the tree-type of the Dicotyledones with that of the Monocotyledones we see at once the feature I refer to in the adult, which has given the advantage to the dicotylous type in respect of its water-supply. In Dicotyledones we have a much-branched stem ending with numerous shoots with long internodes and small apices, and bearing many small leaves which are mainly deciduous. In the monocotylous tree, of which we may take the palm as a type, there is a straight stem with short internodes, a large apex bearing few large leaves not often renewed; if there be branching it takes more or less the form of a fork. The whole of this external configuration bears relationship to the internal structure. In the Dicotyledon the open bundles of the central vascular system provide through their cambium for a continued increase of the water-carrying system and medullary rays, which, although it is to many a heresy, I hold to have profound influence upon the movement of water in trees. The buttressing of the branches is also secured, and thus is rendered possible a large assimilating area made up of a vast number of small individual surfaces, each one of which can be readily thrown off. In the Monocotyledones, on the other hand, the distribution of a large number of closed vascular bundles in a matrix without a cambium involves the provision of a broad terminal cone, gives no support, outside interstitial growth, to lateral branches, which are consequently when developed placed so as to give an equipose, and the assimilating surface has to be concentrated in a few large leaves. The possession of cambium has enabled the Dicotyledones to meet in a much better way the requirements of water-supply and strength in correlation with feeding.

The general uniformity and effectiveness of the scheme of cambial growth is a remarkable feature in the dicotylous type; but there is still a wide field of investi-

[1] I use the term purely as an objective designation, and in the original meaning of the suctorial organ in the embryo. This terminal cotyledon in the Monocotyledones is not a leaf nor the homologue of the lateral cotyledones in the Dicotyledones. The 'traceable and direct developmental history in the formation' of the two organs is clear, and they are not alike. To those who hold the contrary view a terminal leaf is no obstacle. I think, however, the question of lateral or terminal is of importance in organography. The 'sympodial leaf-from-leaf evolution,' described in the first epicotylar stages of Juncus, Pistia, and other plants, demands examination with the aid of modern methods. All cases of vegetative organs in which the distinctions between organs are said to break down are worthy of being looked at in the light of their relation to their nutritive environment. How nutrition affects plant-form we do not yet understand. Its effects are familiar, both in vegetative and reproductive organs. The grosser cases, in parasites, show in the extremes an abolition of most of the landmarks of morphology—'the whole scheme of formation of organs is jumbled.' Heterotrophic 'jumbles' do not, however, deny the ordinary morphological categories. Pseudo-terminal reproductive organs are to be expected under the cessation of growth with which their development is concurrent.

gation in the relationships of size and distribution of vasa both to the other structural elements of the stem and to the form of the plant in relation to its environment. So far as I know the monocotylous tree-forms, there has been an attempt in two different directions to provide an increased water-carrying system in them. There is the familiar one of the secondary cortical cambium in Dracæna and other genera. In them the cambium merely repeats in its products the construction of the primary stem, and does not provide so copious an increase of carrying area as does the system in dicotylous plants. And then in such plants as Barbacenia, many Bromeliaceæ, perhaps Kingia, we have an arrangement reminiscent of the superficial root-system which is found in many polystelic arborescent Pteridophytes of the present day. There is a copious growth of adventitious roots from the central vascular cylinder, and these pass down within the cortex, and from its cells are no doubt able to draw water for the upper parts of the stem.[1] Ultimately many of these roots reach the soil. At best, however, neither of these systems has been satisfactory. All that can be said for them is that they have enabled the monocotylous trees in which they are found to hold their own in xerophilous conditions.

Of Phyla within Dicotyledones and Monocotyledones.

A brief reference only to the groups within the Dicotyledones and Monocotyledones must conclude these remarks. Whilst there is a wonderful concurrence in the opinion of botanists as to the natural groups—real phyla, whether termed cohorts, alliances, or series—into which many of the families of both Dicotyledones and Monocotyledones fall, there is irreconcilable divergence of view as to their genetic sequence or sequences. And this is not surprising when we remember that we know nothing of the starting point or points of the classes themselves; and have, moreover, no critical mark by which to diagnose a primitive from a reduced feature in many of the flower constructions to which, as characteristic of Angiosperms, importance is attached. The desire to establish a monophyletic sequence of these phyla is natural, and finds expression in pedigrees of Dicotyledones issuing from, it may be, Ranales or Piperales, of Monocotyledones from, say, Apocarpæ or Arales. But all such attempts appear to me, in the present state of our knowledge, to be in vain. We see in the phyla, as we know them, culminating series in our epoch in lines of descent; some, for instance Myrtales or Lamiales, progressive; others, like Primulales or Pandales, apparently not so. We also recognise that these series group themselves in many cases as branches of broader lines of descent; for example, in the Bicarpellatæ of Gamopetalæ, in the Helobieæ of Monocotyledones. To a greater or less degree such relationships are traceable now, and as we obtain more knowledge of the angiospermous plant-life of the world they will be widened. But this is a different thing from the carrying back the pedigree of every phylum of dicotylous and monocotylous plants to one or other of the existing ones, which may possess what are taken to be elementary characters. We have, so far as I know, no evidence to sanction the belief, or even the expectation, that there is extant any family of Dicotyledones or Monocotyledones which represents, even approximately, a primitive type in either class. The stem in each has gone. We have the twigs upon a few broken branches.

Amongst the phyla we cannot discern any one type that can be described as the dominant one. The multifarious adaptability of the angiospermous type has given us diverse forms, suited, as far as we discern, no less well to the varied environments of our epoch. Yet we are able to differentiate certain of them which take precedence alike in point of number of species and in area of distribution. If we seek for some general character that marks these advanced groups we find it in the tendency to greater investiture of the ovule, both in Dicotyledones and Monocotyledones. This is brought about in different ways; for instance, by the sinking of the gynæceum in the torus as in Compositæ, by inclusion within a

[1] I leave it to Palæophytologists to say whether this construction may sometimes account for the profusion of roots alongside of stem-structure in fossil-sections.

persistent calyx as in Labiatæ, or within bracts as in Gramineæ. This feature, it will be observed, emphasises that which I have put in the forefront, as leading to the establishment of the angiospermous type. That it must give greater security to the embryo in relation to its water-supply is obvious, although it has evidently also direct connection with seed-dispersal. Another general character observed in these higher groups is the greater security for economical pollination afforded by the adaptations in relation to insect-visits. At the same time the case of the Gramineæ shows us that other adaptations in this respect are not incompatible with prominence.

I will not dwell upon the influence of water upon the vegetative organs in Dicotyledones and Monocotyledones. Of all the factors of environment its effects are best known because most easily seen. The examination of plants from the standpoint of their relation to water—bearing in mind that this is physiological, and not merely physical—has already thrown a flood of light upon their forms and upon their distribution, and offers a fertile field of investigation for the future.

Water has been, then, a dominating influence at all periods in the evolution of our vegetation. The picture of its claim in this respect which I have presented to you is drawn in the broadest outline, and with the intention more of recalling points of view from which familiar facts in the life of plants may be looked at. It is just occasions like this which give the opportunity of telling to a competent audience of the impressions received by one's most recent glimpse in the kaleidoscope of plant-life. It is in this spirit I offer my imperfect sketch.

The following Papers and Reports were read :—

1. *The International Association of Botanists.* *By* Dr. J. P. Lotsy.

2. *Cytology of the Cyanophyceæ.* *By* Harold Wager.

The researches of Scott, Zacharias, and others have definitely revealed the fact that the contents of the cells of the Cyanophyceæ are differentiated into two distinct portions, an outer peripheral layer in which the colouring matters are placed and a central colourless portion which is usually spoken of as the 'central body.' The central body is regarded by many observers, and notably by Bütschli, as a true nucleus. So far as my own observations go, it appears to me to resemble the nuclei of higher organisms in that it is composed of a chromatic network, but differs from them in the absence of a nuclear membrane and nucleolus. Staining and other reactions show that chromatin is present, but in most cases only in small quantities. The presence of phosphorus in the central body can also be demonstrated, as Macallum has shown, by means of the molybdate, phenyl-hydrazin reaction.

In the process of division the cell begins to divide and new cell walls formed independently of the division of the nucleus.

In the process of nuclear division the chromatin threads become drawn out longitudinally and parallel to one another, and are then divided transversely. Some of the division stages, especially in elongate cells, resemble stages in true karyokinetic division.

Various staining methods can be employed to render the structure of the central body visible, but it is more clearly demonstrated in some species than others.

The colouring matter is not distributed evenly through the peripheral layer. It occurs in the form of granules or fibrils. The structure of the peripheral layer recalls that of the chromatophores found in other organisms. It consists of a colourless and a coloured portion, and the coloured portion appears, as before mentioned, fibrillar or granular.

The investigation of the cell structure of the Cyanophyceæ is not interfered with to any considerable extent by plasmolysis phenomena.

The action of artificial digestive fluid is not very reliable as affording a clue to the nature of the central body, although it often helps to render its structure more clearly visible when the cells are subsequently stained.

3. *Some Botanical Photographs from the Malay Peninsula.* *By* R. H. YAPP.

4. *The Diameter Increment of Trees.* *By* A. W. BORTHWICK, *B.Sc.*

There are two methods by which the rate of growth in thickness or diameter increment of trees can be ascertained. One of these methods is to measure annually or at certain intervals the diameter or circumference by means of tree callipers or a tape. The only other method of investigating the diameter increment on standing trees is by means of a very useful instrument known as Pressler's increment-borer. By means of this instrument cylinders of wood, about a quarter of an inch in diameter and from two to six inches long—according to species—can be extracted, and upon those the breadth of the year-rings measured. In order to allow for any irregularity of growth it is safer to take the mean of four cylinders, one from each end of two diameters at right angles to each other. The great difference between the two methods is that the latter requires only a few minutes, while the former requires years to give reliable results. It is therefore of some interest and importance to know how the results got by both methods agree. But unfortunately, in very few cases have careful measurements extending over a long period of time been carried out. In fact, in the whole history of British arboriculture there is no other place where more extensive and careful records have been kept than in the Royal Botanic Garden, Edinburgh. So far back as the year 1875 the late Sir Robert Christison began a series of systematic girth measurements on marked trees in the garden, and since his death in the year 1882 these observations have been carried on by Dr. David Christison, who has recently published some of his interesting results in the 'Notes from the Royal Botanic Garden.'

Through the kindness of Professor Bayley Balfour I have had the rare opportunity of testing whether the increment-borer would yield the same, or approximately the same, results as the tape. On comparing the results obtained by both methods it was extremely interesting to find how closely they coincided. The actual figures are not the same, because the borings were not taken at the same level as the tape measurements. They were purposely taken slightly higher or lower, as seemed expedient, in order not to interfere with the marked circumference measured by Dr. Christison. Although the actual figures for each year do not coincide, the mean or average for a period of five or ten years does correspond very closely.

5. *On the Absorption of Ammonia from Polluted Sea-water by the* Ulva latissima. *By* Professor LETTS, *D.Sc., Ph.D., and* JOHN HAWTHORNE, *B.A.*

In a previous research[1] it was shown that the occurrence of this sea-weed in quantity in a given locality is associated with the pollution of the sea-water by sewage, the evidence being of three kinds: (1) The high proportion of nitrogen contained in the tissues of the *ulva*; (2) an examination of certain localities in which the sea-weed occurs in abundance, and of others from which it is virtually absent; and (3) experiments on the assimilation of nitrogenous compounds by the growing *ulva* from sea-water artificially polluted.

Commencing these latter experiments somewhat cautiously, it was first

[1] *B.A. Report*, 1900, and *Proc. Roy. Soc. Edin.*, 1901, p. 268.

proved that all the ammonia was removed from a sample of sea-water considered to be somewhat highly polluted (0·046 part ammonia per 100,000) by a few days' contact with the sea-weed. Next it was found that the absorption occurred in less than twenty-four hours, while later experiments have shown that the remarkable power of assimilating ammonia which the sea-weed possesses had been altogether underestimated, as well as the rapidity with which the absorption occurs. The method of experiment was that previously employed. A sample of the polluted sea-water was first analysed and placed in a glass dish. Next a frond of the *ulva* was immersed in it, and finally portions of the sea-water withdrawn and again analysed after suitable intervals. Two different series of experiments were made, the first with a solution of ammonium chloride in pure sea-water, and the second with a mixture of sea-water and the effluent resulting from the treatment of sewage by the so-called 'Bacteria Beds.' All the experiments in the first series were made with the same piece of sea-weed, which had an area of about 200 square inches; and a similar remark applies to the second series, in which, however, several pieces of sea-weed were used having a total area of about 600 square inches. Individual experiments in both series were made to test the absorptive power of the *ulva* in relation to concentration (of the ammonia), as well as the effects of light and darkness. The following table gives the chief results obtained:—

Absorption of Ammonia by Ulva latissima *from*—

Solution of Ammonium Chloride and Sea-water (Area of Fronds 200 Square Inches) (Volume of Mixture, 2½ Litres)

No. of Experiment	Parts of Ammonia per 100,000 of liquid originally present	Percentage of Ammonia Absorbed after 1 Hour	2 Hours	3 Hours	4 Hours	5 Hours	In
1A	0·085	59	81	91	—	—	Daylight.
5A	0·180	58	88	96	97	—	Daylight.
4A	0·085	37	77	87	91	—	Darkness.
7A	0·960	29	41	56	67	75	Darkness.

Mixture of Bacteria Bed Effluent and Sea-water (Area of Fronds 600 Square Inches) (Volume of Mixture, 2½ Litres)

No. of Experiment	Parts of Ammonia per 100,000 of liquid originally present	Percentage of Ammonia Absorbed after 1 Hour	2 Hours	3 Hours	4 Hours	5 Hours	In
1E	0·084	64	82	91	—	—	Daylight.
6E	0·412	59	86	96	98	99	Daylight.
3E	0·080	18	45	58	—	—	
4E	0·095	58				96	
	0·532	43	63	73	98	—	

The general conclusions to be drawn from the experiments are as follows:—

(1) The absorption of ammonia by the sea-weed is very rapid, and with the mixtures used practically all the ammonia was absorbed in five hours (with one exception, when 75 per cent. was lost).

(2) The amount absorbed is greatest during the first hour of contact, and then rapidly falls off.

(3) Although the concentration of the ammonia exercises some effect on the proportion absorbed, it is by no means so considerable as might have been expected.

(4) The sea-weed absorbs ammonia both in daylight and in darkness, but the proportion in the latter case is rather less than in the former.

(5) The effects of an increased area of the sea-weed on the proportion of ammonia absorbed are not so great as might have been expected.

These results may be of practical importance in those districts where a serious nuisance results from the decay of large quantities of the *ulva* which have been washed ashore, or which have accumulated in shallow water. For it seems probable that by allowing the effluent from the bacterial treatment of sewage (which treatment gets rid of much of the ammonia originally present) to remain in contact with the growing *ulva* in specially constructed ponds containing sea-water,

before discharging it into the sea itself, the ammonia or nitrate will be absorbed, and that the mixture of effluent and sea-water will then no longer provide nourishment for the *ulva* in the sea itself, and that consequently the sea-weed will be so much reduced in quantity in the district as to cease to give rise to a nuisance.

The stimulating effects of the ammonia or effluent were evident from the rapid evolution of oxygen from the surface of the sea-weed, which always occurred about fifteen minutes after the addition of the polluting substance, and forms a pretty experiment.

In two cases the dissolved gases were extracted from the sea-water in which the *ulva* was immersed (by boiling out with dilute sulphuric acid *in vacuo*) immediately after adding the polluting material, and again some hours later, and analyses made. The following results were obtained:—

Experiment 5A (*Daylight*).

Immediately after adding Ammonium Chloride (0·180 part per 100,000) (c.c. per Litre at N.T.P.)	Four Hours Later
T = 14·4	T = 15·9
CO_2 ... 21·69	15·90
O_2 ... 11·41	14·84
N_2 ... 9·79	9·88
Loss of CO_2 = 5·79 c.c.	Gain of O_2 = 3·43 c.c.

(About 2 c.c. of evolved oxygen gas were also collected.)

Experiment 8E (*Darkness*).

Immediately after adding Effluent (20 per cent.)	Four Hours Later
T = 14·6	T = 14·8
CO_2 ... 63·59	66·44
O_2 ... 6·31	3·85
N_2 ... 11·90	11·74
Gain of CO_2 = 2·85 c.c.	Loss of O_2 = 2·46 c.c.

In 5A the *ulva* had been in contact with the sea-water for a considerable time, whereas in 8E fresh sea-water was used.

The above analyses are interesting in several ways. First, in Experiment 5A, the amount of oxygen found is greatly in excess of the value given by Dittmar in the 'Challenger' Reports for the volume of oxygen which one litre of sea-water can take up when saturated with constantly renewed air at the existing temperature, Dittmar's figure for 15° C. being 5·83 c.c. The action of the *ulva* is therefore, in a sense, to *supersaturate* the sea-water with oxygen under the existing conditions.

Secondly, the amount of carbonic anhydride found (in the same experiment) is much less than that present in normal sea-water, Dittmar's average for the total volume in sea-water being about 48 c.c. per litre, of which in all probability some 40 c.c. are in the form of soluble bicarbonate of calcium or magnesium. It is evident therefore that the *ulva* gains its carbon from the carbonic anhydride of these salts.

Thirdly, the results of the experiment in darkness demonstrate in an interesting manner the true respiration of the *ulva*, carbonic anhydride being evolved in practically the same amount as the oxygen disappearing.

6. *Notes on* Stellaria holostea *and Allied Species. By* John Paterson.

Biology.—The shoots appear in early spring before the development of the grasses. The leaves are arranged parallel to the stem axis in bud condition. They open out and grasp the leaves of the grasses and other herbage as these develop,

being thus delicately balanced. The leaves are elastic and tend to return to their original position when displaced.

The young shoots are rigid, but the older parts become elastic and flexible, so that the stem is kept erect by the leaves clinging to other plants, and falls down when detached. When the plant withers in autumn the stems fall to the ground and continue their growth by buds which arise alternately in the axils of some of the leaves; the branches are thus able to extend over a large area in a manner which would be impossible if they remained erect.

Anatomy.—The epidermis has cuticularised walls. The cortex is turgid, consisting of large cells with strengthening tissue at the corners, which act like pillars, keeping the central cylinder stretched out.

The endodermis is very distinct. The pericycle and tissue formed from it are several cells thick.

There are six vascular bundles separated by primary medullary rays. There are pith cells, but the stem is hollow in the centre. In an older stem the cortex withers and becomes detached from the central cylinder, though the ruptured endodermis cells still persist, and the central cylinder then contracts and the vascular bundles become consolidated, whilst the primary medullary rays become more or less obliterated. A continuous cork sheath, several layers thick, is then formed from the pericycle. Adventitious roots arise at the nodes of the older stems.

The arrangements in *Stellaria graminea, S. uliginosa, S. media, S. nemorum, S. glauca,* and other Caryophyllaceæ are shortly compared.

7. *The Morphology of the 'Flowers' of* Cephalotaxus. *By* W. C. Worsdell.

Male 'Flowers.'

Comparison of structure with that of the allied genera *Ginkgo, Taxus, Torreya, Phyllocladus.* History of views on subject: *Eichler* and *Čelakovský.*

Female 'Flowers.'

Account of comparative structure of normal 'flower.' History of views on subject: *Eichler, Strasburger, Van Tieghem, Čelakovský.* Author considers the view on the morphology held by last-mentioned writer as the only tenable one.

Original observations on *proliferated* inflorescences and 'flowers.' Proliferation of both primary and secondary ('floral') axes occurs. Latter consists in elongation of an axillary axis on which the two ovules are situated laterally, and which may produce rudimentary foliar organs both above and below insertion of ovules. Ovules may also appear as rudimentary foliar organs borne on the axillary axis. This fact appears to author to refute the axial theory of ovule of Eichler and Strasburger, and to support the foliolar theory of same put forward by Čelakovský. Value of metamorphogenesis as an aid to determining morphology of any recondite structure is illustrated in case of *Cephalotaxus.*

8. *The Morphology of the Ovule. An Historical Sketch.* *By* W. C. Worsdell.

Three principal views as to morphology of ovule have been held:—

1. *Axial Theory.*

On this theory the ovule is an organ of *axial* structure, the nucellus representing a bud, and the integuments the first-formed foliar organs thereof. Chief propounders of this view, *von Mohl* (1851), *Schacht* (1850), *Endlicher* and *Unger* (1843), *Alex. Braun* (1860).

2. *Foliolar Theory.*

On this theory the ovule is homologous with a *leaflet* of a carpel, viz., the integuments with the terminal and two lateral segments of the leaflet, and the nucellus with an emergence borne on the upper or ventral surface of the former; the nucellus is thus directly homologous with an eusporangium, such as that of *Angiopteris*. Primitive position of nucellus or sporangium is *terminal* to leaflet, as is case in normal ovule, where the homologue of leaflet of carpel takes the form of one or two urceolate envelopes. Case of Ferns where sporangium is usually borne on lower surface of leaflet is an instance of progressive metamorphosis from the primitive condition; here the green leaflet, or its receptacular representative, is the homologue of the outer integument of the ovule, and the indusium of the inner integument of the latter. The leptosporangium of most ferns is the result merely of the ultimate subdivision of the eusporangium, and is homologous with a *trichome*. The abnormalities resulting from the metamorphogenesis of the parts of the ovule are the decisive and only reliable sources for determining the true morphology of the ovule. Chief propounders of this theory are *Brongniart* (the founder, 1834); *Cramer* (1864), *Čelakovský* (1874–1900), *Eichler* (1875), *Warming* (1878). Of these, Čelakovský is responsible for the formulation of the theory as above summarised.

3. Sui generis *Theory.*

This theory holds that the sporangium, with its homologue the nucellus, is an organ *sui generis*, and cannot be included under any of the morphological categories of stem, root, leaf, or trichome. The integuments are new structures arising on the sporangium or nucellus. The abnormalities are of no permanent value for determining the morphological relationships of the parts concerned. The chief upholders of this view are *Sachs* (1874), *Goebel* (1887), *Schmitz* (1872), *Strasburger* (1879), *Bower* (1894).

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9. *The Histology of the Sieve Tubes of* Pinus. *By* A. W. Hill.

The sieve tubes of Gymnosperms have been previously investigated by De Bary, Janczewski, Russow, Keinitz-Gerloff, and Strasburger especially with reference to the structure of the sieve plate and the mode of communication between adjoining sieve tubes.

The present researches have proved that the results obtained by Russow are, in the main, correct; for it has been found, as he describes, that the mature sieve plate is traversed by groups of callus rods, which are interrupted at the middle lamella by median nodules, and that each callus rod contains from three to seven striæ—or spots if examined in surface view—which are strings of slime.

With questions of development Russow was not very successful, and it is with them that the chief interest of the research lies.

The youngest sieve plates or pit-closing membranes, which could be examined, showed 'connecting threads' like those in ordinary tissue; but in the so-called 'boundary cells'—*i.e.*, the youngest thick-walled sieve tubes—a change takes place, namely, the appearance of the callus. Callus first appears on one surface of the sieve plate, at the places where the groups of 'connecting threads' occur, and it gradually spreads as a rod along a group of the threads to the middle lamella; a similar change then takes place on the other side of the lamella. The lamella itself, however, is not converted into callus, but a refractive median nodule appears separating the two portions of the callus rod.

Accompanying this change the protoplasmic threads become converted into slime strings. A similar state of things obtains in part with the sieves between the sieve tubes and the albuminous cells.

The changes just described are without doubt due to the action of ferments, which travelling along the threads convert them into slime strings and at the same time alter the cellulose portion of the pit-closing membrane in their

neighbourhood into callus, forming the callus rods. The subsequent increase of the callus to form the callus cushions is due to the activity of the protoplasm.

10. *Report on Fertilisation in Phæophyceæ.*—See Reports, p. 118.

11. *Report on the Morphology, Ecology, and Taxonomy of the Podostemaceæ.*—See Reports, p. 447.

FRIDAY, SEPTEMBER 13.

The following Papers were read:—

1. *On Correlation in the Growth of Roots and Shoots. By* Professor L. KNY.

The objections made to the author's former paper on the same subject[1] by Heering[2] are here criticised. If in his first paper he only gave the final result of his experiments and not the detailed steps by which the first result was brought about, he did so because the removal of the root or of the shoot from the seedlings must at first cause a shock to the organism and disturb its development, quite independent of any correlation. This anticipation was shown to be true by the careful studies of Townsend.[3]

Of the experiments which he made after the publication of his first paper he quotes one with respect to cuttings of *Ampelopsis quinquefolia*. From this experiment it follows that, just as in the cuttings of *Salix acuminata* and *S. purpurea*, the continual removal of the young shoots was soon followed by a less vigorous development of roots, and *vice versa*. There is, however, this difference to be noted, that, whereas in *Salix* the retarding influence is to be detected first in the roots, in *Ampelopsis* there are the shoots, which in this case proved themselves to be more sensitive than the roots.

The paper will be published in full in the 'Annals of Botany.

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2. *The Bromes and their Brown Rust. By* Prof. MARSHALL WARD, *F.R.S.*

The author has been for some time occupied with the grasses of the genus *Bromus* and the behaviour of the uredo of the brown rust (*Puccinia dispersa*) upon them. The work has entailed careful examination of the seeds and seedlings of a large number of European and foreign Bromes and critical analyses of the anatomical and morphological characters used in the systematic botany of the group.

The plan of the investigation includes the nature of infection and conditions of attack, and all discoverable relations between host and parasite.

The germination of the grass seeds has led to interesting points. They can be treated antiseptically in various ways and grown as pure cultures in nutritive solutions in glass tubes of various shapes, designed either to allow of the continuous aëration of the plantlet by a current of filtered air drawn through by aspirators, or not.

Such pure cultures of the grass were then infected with uredo-spores, and in ten to twelve days gave rise to *pure cultures of the uredo*, which germinated and infected other similarly pure cultures of the grass inoculated with them. Control cultures

[1] *Ann. Bot.*, viii. 1894, p. 265. [2] *Jahrb. f. w. Bot.*, xxix. 1896, p 132.
[3] *Ann. Bot.*, xi. 1897, p. 509 ff.

in tubes, but not infected, gave rise to no uredo, even if raised from the seeds of diseased plants. The pustules of uredo only originate at that spot on the leaves where the uredo-spores were sown.

These results lend no support, therefore, to any hypothesis of internal or seminal infection.

Long series of sowings were made to test the conditions of germination of the uredo-spores, for, strange as it may seem, little attention has been paid to this matter. The minima and maxima temperatures of germination are about 10° C. and 27°·5 C. respectively, the optimum being about 18° C. Many failures in infections are due to the non-germination of the spores in hot weather.

The effects of light, of other organisms (*e.g.*, Algæ), of various extracts, and of the age of spores, &c., were also examined.

The uredo-spores may be frozen for ten minutes, but will not recover after two hours' freezing.

Infection experiments on pot plants were made—several hundreds in all—on twenty-one species or varieties of *Bromus*.

The general results are, put very shortly, as follows: Although the uredo examined is in all morphological respects absolutely identical on all the species of *Bromus* on which it occurs, nevertheless if spores gathered from *B. sterilis* are sown on *B. mollis* the infection fails, whereas spores of the same batch sown on *B. sterilis* infect normally and rapidly. And similarly in other cases. Spores from *B. mollis* readily infect *B. mollis*, and (less certainly) its allies *B. secalinus* and *B. velutinus*, *B. arvensis* and others of the *Serrafalcus* group; but they fail on *B. maximus*, *B. tectorum*, *B. sterilis*, *B. madritensis*, &c.—the *Stenobromus* group—and so with other cases.

[TABLES I. and II.]

In the annexed tables (I. and II.) are tabulated the results obtained in seven of the experimental series. The tables explain themselves, but it may be well to note that the species of *Bromus* employed as host-plants have here been arranged in similar order throughout in order to facilitate comparison. Thus *B. erectus* to *B. ciliatus* are representatives of the first group (*Festucoides*); *B. tectorum* to *B. maximus*, inclusive, of the second group (*Stenobromus*); *B. secalinus* to *B. macrostachys*, inclusive, of the third group (*Serrafalcus*); and *B. unioloides*, with which *B. Schraderi* is synonymous, of the fifth group (*Ceratochloa*). The author has not yet had time to examine *B. arduennensis* (fourth group), and in a few cases the series of experiments are too few for any statements of value as to details. But it seems clear that the general statement is sufficiently proved as regards groups 2 and 3 at least.

The series selected for tabulation in the foregoing tables are only a few taken from the numerous sets of similar experiments. This is hardly the place for reproduction of many other details, but in order to give some idea of the enormous amount of labour involved in such an investigation, another table (III.) is appended giving a summary of all the series of this season's pot-plants under normal conditions only, exclusive of experiments with tubes and with extraordinary conditions such as diminished mineral supplies, and so forth.

Here, again, it will be seen that the general accuracy of the conclusions put forth is fully evident, though a detailed examination of the series—conditions of infection, incubation, &c.—is necessary for the explanation of one or two apparent discrepancies—*e.g.*, to explain why the percentage of failures was so high with *B. velutinus* infected with spores from *B. secalinus*. These matters must be left for future treatment, and in some cases for further experiments next season.

[TABLE III.]

Thus, in the annexed Table III. we see that eighty-five plants of *B. mollis* were inoculated with uredo-spores derived from *B. mollis*, of which sixty (over 70 per cent.) gave positive results, *i.e.*, actually developed pustules at the spots inoculated; but it should be noted that in many cases here recorded as failures—because I put

as negative all cases where no pustules appear—distinct flecks were formed on the leaves; eighty-four plants of the same species (*B. mollis*) were inoculated with spores derived from *B. sterilis* but none succeeded, and eight were tried with spores from *B. secalinus*, of which three (37·5 per cent.) succeeded and five failed.

Again, looking at *B. sterilis*, we find that eighty-six out of ninety attempts to infect this species with spores from *B. mollis* failed, whereas sixty-eight out of eighty-four (81 per cent.) attempts to inoculate the same species succeeded when the spores used were derived also from *B. sterilis*. All the eighteen plants inoculated with spores from *B. secalinus* proved immune.

Having regard to the morphological groups of these Bromes, it is found that any given species or variety is most easily infected by spores which have been grown on the same species or variety, less certainly by spores from allied species, and not at all successfully by spores from a species in another group. Some interesting details regarding the relations between host and parasite in infection are also to hand.

Three stages of development on the part of the uredo must be distinguished: (1) The germination of the spore and development of the germ-tube; (2) the entrance of the latter as an infection-tube through the stoma of the grass; and (3) the growth of the latter into a branched mycelium in the intercellular spaces of the host, into the cells of which it sends haustoria, and finally—about the tenth day after sowing—again puts forth spores as it breaks out through the stomata in the form of the well-known rust-pustules. This last period may be termed the incubation period.

The author finds that various exigencies, especially of the weather, affect the fungus during each of these three periods.

Infection may fail because the temperature is too high or too low during the germination period, or the germ-tubes may dry up, or be killed in other ways.

On reaching a stoma the successful entrance of the germ-tube, as an infecting tube, depends on various factors, of which the specific nature of the Brome attacked is an important one. Taking spores derived from *B. mollis*, for example, their germ-tubes appear to so corrode and destroy the tissues of *B. sterilis* that the spot where the sowing is made turns black and dies, and no successful infection occurred; on *B. maximus*, *B. inermis*, and others, on the other hand, no successful attack is, as a rule, established at all.

Even when the infecting tube has established an entrance, several events may intervene to prevent successful infection; *i.e.*, the formation of a normal intercellular mycelium which dominates the tissues and ultimately breaks forth from the stomata again as pustules with fresh crops of uredo-spores.

If the host is starved of carbohydrates by partial etiolation, or of minerals by lack of supplies in the soil, or by interference with the transpiration, &c., the mycelium—even in a species normally quite suitable to the parasite—only drags on a miserable existence and has not strength to form spores. In such cases nothing further results than the development of pale, feeble flecks on the leaf. The same thing occurs in some partially immune species, even though flourishing, evidently owing to the refusal of the cells to allow the mycelium to dominate their life.

These antagonistic reactions of the host-plant are not due to any structural peculiarities discoverable by the microscope; nor is it a simple matter of the excretion of any poisonous soluble constituent of the sap, judging from the experiments in which uredo-spores derived, for example, from *B. mollis* germinated satisfactorily in both boiled and unboiled aqueous extracts of the leaves of *B. sterilis*, which had been previously filtered through stone filters under pressure. In addition to the case of successful and normal infection, therefore, three distinct cases of failure to infect can be distinguished: (1) in which the preliminary establishment of an infecting mycelium is assured, but this remains dormant, *i.e.*, fails to dominate the living cells of the leaf, and only a pale yellowish fleck results; (2) in which the attack of the germ-tube is so vigorous that it kills the guard-cells and tissues, and produces a black corrosion spot in which the parasite can make no progress; (3) complete immunity; the parasite fails to get any hold on the leaf

at all, and the latter is as green and healthy-looking at the end of the normal incubation period as before inoculation.

These observations lend no support to either the Mycoplasm theory of Eriksson, or to any theory which attempts to explain outbreaks of rust to intra-seminal infection handed down from parent to offspring, and the author believes that the difficulties hitherto met with in understanding the sudden epidemics of these rust-diseases will disappear as we gain exact information of the conditions of germination, infection, and incubation of the disease-producing parasite; as also of its habits of lurking in the older leaves of the grass in spots where the production of a very few spores—quite invisible on a casual overhauling of the grass—prepares the way for more extensive infection as the weather changes.

On the other hand, they throw considerable light on the question of adaptive parasitism, and show that the previous nutrition of the uredo-spores affects their parasitic power, with regard to another host-species, in much the same way that the previous nutrition affects any other disease germ—*e.g.*, certain bacteria—or even saprophytes—*e.g.*, certain yeasts and fungi. If only one in a million of the spores once manages to gain a hold on a species or variety hitherto immune, its spore progeny can now successfully attack that species or variety; and in proportion as it becomes more and more specially adapted to life in the tissues of this new host will it find difficulties in going back to its old host or forwards to another, and

3. *The Past History of the Yew in Great Britain and Ireland.*[1] *By* Professor H. Conwentz, *Danzig.*

Many years ago the author studied the distribution of this species, and he has inquired as to the causes of its disappearance in nearly all the countries of the middle and north of Europe; also in the British Isles. It is his opinion that there are three points which prove a previous wider distribution, viz., sub-fossil remains, prehistoric and historic antiquities, and place-names. By microscopical examination he has found a great number of sub-fossil yew trees from submerged forests and other localities in England and Ireland. Then he has examined the prehistoric wooden boxes, buckets, &c., in the British Museum, London, in the Science and Art Museum, Dublin, &c., and he has identified more than thirty with *Taxus*. Attention is drawn to the names of uninhabited places, which in former times were very often called after indigenous trees. He has made out a number of some hundreds of English, Scottish, and especially of Irish place-names from the yew which are not unworthy of being considered by botanists. Guided by the names of such localities in Germany, he has dug into the ground, and has found sub-fossil remains of the yew. Therefore he has suggested researches of this kind also in the British Isles, and he would be glad to get small pieces of bog wood for examination.

The genus is not of a considerable geological age, as nearly all Tertiary remains described under the name of *Taxus* are *not* yew.

4. *On the Distribution of Certain Forest Trees in Scotland, as shown by the Investigation of Post-Glacial Deposits.* *By* W. N. Niven.

The information has been chiefly obtained from occasional references in many topographical books of Scotland to the discovery of various trees in particular districts.

The following are some of the volumes (about seventy in number) from which information has been derived:—

'New Statistical Account.' 15 volumes. 1845.
'Old Statistical Account.' 21 volumes. 1791–99.

[1] The paper will be published by the Royal Irish Academy.

'A Practical Treatise on Peat Moss.' Anderson. 1794.
'Edinburgh Philosophical Journal.' Volumes iii., vii.
'Transactions of the Royal Society of Edinburgh.' Volume ix.
'Transactions of the Inverness Scientific Society.' Volume iii.
'Vertebrate Fauna of Moray.'
'Cairngorm Club Journal.'
'Pennant's Tour in Scotland.' 1769.
'Woods, Forests, and Estates of Perthshire.' Thos. Hunter.
'Transactions of the Buchan Field Club.' Volume iv.
'Transactions of the Dumfries and Galloway Natural History and Antiquarian Society.'
'Annals of Scottish Natural History.' Nos. 23–25.
'Tour through Orkney and Shetland.' George Low. 1774.
'My Schools and Schoolmasters.' Hugh Miller.
'Edinburgh and its Neighbourhood.' Hugh Miller.
'Origin of the British Flora.' Clement Reid.
'Great Ice Age.' Prof. James Geikie.
'Prehistoric Europe.' Prof. James Geikie.
And others.

The following trees have been discovered:—Hawthorn, elder, common ash, birch, alder, hazel, oak, willow, yew, and fir, all of which, with the exception of the ash, are considered natives of Scotland. The cones of the silver fir have been dug out of the peat in Orkney, but this tree is not now indigenous to Scotland. Several shrubs, including the juniper and raspberry, as well as many flowering plants, have also been discovered.

On a map prepared by the author the localities are marked where the various trees have been found. The records are probably not complete, but are sufficient to show the distribution.

It will be seen that there are few parts of Scotland, however treeless at the present day, that were not in remote, and even in comparatively recent times covered with woodlands. This is also shown by the place-names. As regards the special trees:—

The oak is very widely distributed. Its most northern occurrence is Caithness-shire, and it is recorded in every other county. It has even been found in the peat bogs in the now treeless islands of Lewis and Tiree.

It is interesting to note that many of the oaks have been found at high altitudes, *e.g.*, 800 feet above sea-level (parish of Croy, Inverness-shire), and of considerable size, *e.g.*, 70 feet in length (Drumcrief).

The Scots fir, probably the *Pinus sylvestris*, is another widely distributed tree. It is common in the Northern Counties, in the Orkneys and Lewis, in all the Midland Counties, with the exception of Forfar and Fife, but in the Southern Counties it is only recorded in Renfrew, Edinburgh, Roxburgh, Dumfries, and Wigtown.

The hazel has been found in the submerged forests, and in many other parts of the mainland, as well as in the Orkney and Shetland Islands and in many of the Western Isles. No record has been found of its occurrence in Sutherland, but throughout the Midlands it is fairly plentiful, and in the Lowlands it has been noted in all the counties, with the exception of Haddington, Linlithgow, Selkirk, Dumfries, and Wigtown.

The birch is recorded in the Orkney and Shetland Islands, and in the majority of the counties from Caithness to Wigtown.

Regarding the other trees few records have been discovered. The alder is recorded from Lewis, Banff, Aberdeen, Kincardine, Perth, Fife, Argyll, Lanark, and Edinburgh. Willows (species unknown) are noted in both Caithness and Sutherland. They have also been obtained from the peat bogs in Renfrew, Lanark, and Roxburgh. The ash is generally regarded as a probable native in the south of Scotland.

Hugh Miller, in 'Edinburgh and its Neighbourhood,' makes reference to finding 'what appears to be ash' in the brickclays of Portobello. It is also recorded from the mosses in Ballantrae, Ayrshire,[1] and Bowden Parish, Roxburghshire.[2] Then, again, many of the implements found in Southern Crannogs are reported to be made of ash wood, but it must also be regarded as indigenous in Northern Scotland if we accept its occurrence in the Bay of Keiss, Caithness-shire, mentioned by the writer on Caithness in the 'New Statistical Account' (vol. xv. p. 129).

The only records of the occurrence of the hawthorn, yew, and elder have been obtained from Edinburghshire.

In conclusion, the evidence, which is obtained by the examination of the various post-Glacial deposits, indicates in a very clear manner that the trees recorded should be considered truly indigenous to Scotland.

5. Professor J. REYNOLDS GREEN, *M.A.*, *F.R.S.*, *delivered a Lecture on Flesh-eating Plants.*

6. *Contributions to our Knowledge of the Gametophyte in the Ophioglossales and Lycopodiales.* *By* WILLIAM H. LANG, *M.B.*, *D.Sc.*

1. The prothalli of *Ophioglossum pendulum* and *Helminthostachys zeylanica.*

The wholly saprophytic prothallus of *O. pendulum* was found in humus collected by epiphytic ferns in Ceylon. It is at first button-shaped, but by branching the older prothalli come to consist of a number of short cylindrical branches radiating into the humus. The apices are smooth and convex; the surface of the older parts is covered with short unicellular hairs. Rhizoids are absent. The young prothallus and the branches are radially symmetrical. In the older parts all the cells except the superficial layers contain an endophytic fungus; nearer the apex the central strand of tissue becomes free from fungus. The prothallus is monœcious. The antheridia are sunken, with a slightly convex outer wall one layer of cells thick; in surface view this shows a triangular opercular cell. The neck of the archegonium, which projects very slightly, consists of about sixteen cells in four rows. The central series in all archegonia yet observed consists of ovum and a single canal cell. A basal cell is present.

The prothalli of *Helminthostachys* were found a few inches below the surface of the soil in a frequently flooded jungle in Ceylon. The sporophyte is also abundant in drier situations, but young plants found there were of vegetative origin. The prothalli, which have not been observed to branch, are radially symmetrical. The smallest were stout cylindrical structures the lower part of which was darker in tint and bore rhizoids; the upper bore the sexual organs, which arise acropetally behind the conical apical region. In the vegetative region the internal cells contain a mycorhizal fungus; in older prothalli this may extend into the lower part of the sexual region. In prothalli which bear archegonia the vegetative region is relatively more developed, and in both these and the male prothalli it becomes more or less lobed. An imperfect distinction of male and female prothalli appears to be the rule, but both archegonia and antheridia may occur on the same prothallus. The antheridia are large and sunken; the slightly convex outer wall is two-layered except at the places where dehiscence may occur, which consist of single large cells. The archegonia have a neck, consisting of four rows of cells, which projects considerably. The details of their structure have not as yet been made out.

2. On the mode of occurrence of the prothallus of *Lycopodium selago* at Clova.

The sporophyte of this plant is very common on moors, screes, and crags in the Clova valley, and in these situations seems to be reproduced almost entirely by

[1] *New Statistical Account*, vol. v. p. 417. [2] *Ibid.*, vol. iii. p. 36.

means of bulbils. On the sometimes submerged margin of Loch Brandy, however, numerous sexually produced plants and prothalli can be found growing in the soil between the stones. The difference in the conditions under which the sporophyte can exist and those necessary for the successful germination of the spores is analogous to what has been found to be the case for *Helminthostachys*.

3. On some large prothalli of *Lycopodium cernuum*.

The prothalli of this plant, described by Treub, were of small size, one of the largest measuring 2 mm. in height by 1 mm. across. On the banks of roads close to Kuala Lumpur much larger prothalli were found. They were cake-like structures, of a deep velvety green colour, about 2 mm. in vertical thickness, but measuring sometimes 6 mm. across: they were attached to the soil by numerous rhizoids springing from the flat base. Such specimens have lost all trace of the definite form which sometimes characterises the smaller prothalli, and are of interest for comparison with the large prothallus next described.

4. On the prothallus of *Psilotum*.

The prothallus of this plant was searched for without success in Ceylon. The sporophyte occurred on tree-fern trunks on Maxwell's Hill in Perak, and a single prothallus was found there embedded among the roots of the tree-fern close to a *Psilotum* plant. No other plants grew on this tree-fern, and, although a few species of *Lycopodium* occur sparingly in the locality, there seems a strong probability in favour of this specimen being the prothallus of *Psilotum*. The specimen measured one quarter of an inch in height by $\frac{3}{16}$ inch across at the widest part. It consists of a cylindrical lower region covered with rhizoids; near the lower end of this is a well-marked conical projection (primary tubercle). The upper part widens out suddenly, and its thick overhanging margin bears numerous antheridia. The summit of the prothallus is depressed and smooth. In general form the prothallus resembles some small specimens of *Lycopodium cernuum*, but the upper region, from which assimilating lobes are absent, finds its closest analogue in prothalli of *L. clavatum*.

7. *Note on an* Ophioglossum *collected by Mr. Ridley. By* Professor F. O. Bower, *F.R.S.*

Professor Bower exhibited a specimen of *Ophioglossum simplex*, n. sp., collected by Mr. Ridley in Sumatra and handed to the author by Professor P. Groom. It appears to be entirely without the *sterile* leaf-lobe, though the fertile spike is characteristically that of an *Ophioglossum*. If it is actually demonstrated that the sterile lobe is really absent, this peculiar plant may give rise to considerable morphological discussion.

8. *Abnormal Secondary Thickening in* Kendrickia Walkeri, *Hook. f. By* Miss A. M. Clark.

1. *Kendrickia Walkeri*, Hook. f., one of the Melastomaceæ, is a tropical epiphytic climbing shrub.

2. The anatomy of the young stem is typical of the family Melastomaceæ.

3. At a fairly early stage numerous small patches and several large wedge-shaped areas of thin-walled unlignified wood-parenchyma are cut off from the inner side of the completely circular cambium ring.

4. Tylosis is of frequent occurrence, and the tylosed cells may develop into sclerotic cells inside the vessels and tracheids.

5. Later the unlignified wood-parenchyma cells at the central margin of the wedge area take upon themselves new growth accompanied by cell division. The product of this new growth proceeds to split the axial woody ring into a varying number of portions, partly by forcing a way between rows of adjoining

tracheids and partly by tyloses into tracheids and vessels, utilising the space contained in the lumen, with subsequent destruction of the identity of these wood elements.

6. Later the quiescent cambium lying between the original internal phloëm and the axial woody ring takes upon itself new growth, and proceeds to lay down xylem on the one side and phloëm on the other.

SATURDAY, SEPTEMBER 14.

The Section did not meet.

MONDAY, SEPTEMBER 16.

A joint Discussion with Section L on 'The Teaching of Botany' was opened by the reading of the following Papers:—

i. *The Teaching of Botany in Schools. By* HAROLD WAGER.

Discussion is invited on the following topics:—Place of botany in the school curriculum as compared with chemistry and physics. Its importance as an educational subject; as a training in scientific method. Amount of time available for it.

Choice of botanical topics suitable for schools. Right selection important. It is not possible or desirable to explore the whole field of botany. 'Intelligent knowledge of a few truths' required rather than an imperfect acquaintance with a vast number of facts. Among the various topics which will be found useful in the school course, experimental plant physiology, especially in connection with nutrition, respiration, and transpiration, is probably one of the most valuable. It affords an excellent training in observation, experimental manipulation, drawing conclusions from facts observed, weighing evidence for and against them, and in neatness and accuracy.

Equipment. Simple laboratory and fittings. Class-room accommodation. Apparatus.

Methods of teaching. The pupil should be led through his own experiments and observations to come to conclusions for himself. The work done in the laboratory should precede any discussion of it in the class-room. Experimental work should not be merely illustrative of the lecture or text-book. As Spencer says, pupils 'should be told as little as possible and induced to discover as much as possible.' Records of experiments. Importance of drawing. Time required by the teacher for the preparation of experimental lessons. Field work. Collecting and collections. Models.

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ii. *The Teaching of Botany in Universities. Notes by* Professor F. O. BOWER.

Preliminaries.—As matters stand at present, no previous study of botany by the student on entry to the university can be presupposed; a knowledge of plants by field collection is, however, most desirable, as well as by such teaching as suggested by Mr. Wager in schools; but microscopic work in schools is not to be encouraged: the time would be better employed in acquiring even the rudiments of French and German. Thus under present conditions any junior class in botany in a university will necessarily be mixed, as regards previous knowledge and scientific method, as much as in intellectual power of the individuals. In

lecturing aim not at the highest nor the lowest intellects, but so as to keep those about 20 per cent. down, with their minds at full stretch.

Protest against so-called 'elementary biology' as an introduction to the study of botany. It was merely a weak concession to circumstances.

Elementary course should be attended by all, even by those who already profess some knowledge of the subject acquired at school, for this course should be a general and methodical foundation for the study on the 'advanced stage, morphological, anatomical, physiological, and systematic. The length of the course should be not less than fifty lectures and a hundred hours of laboratory work closely connected with the subject-matter of the lectures. Observation with the simple lens and drawing the results should bulk more largely than it does at present in laboratory teaching. Microscopic observation has been overdone.

Advanced courses should treat of special branches of the science, and not try to be generally encyclopædic. Each course should lead the student of that special branch up to the limit of present knowledge, with ample reference to, and presentment of, current memoirs; thus the pupil will be introduced to the special literature of the science, and learn how to extend it. Laboratory and herbarium and museum work, ranging over as wide an area of illustration as possible, should accompany each special course.

Advanced students should be left largely to themselves, and thus learn to think and act independently: the object of the student attending advanced courses should be not so much to acquire information, as to learn scientific method, and how to investigate. Microtomes should be accessories, not the divinities, of the laboratory.

Research.—All are not, and cannot be, investigators. Professors should be discreet in encouraging research. At present the results of investigation are given too prominent a place in selection for preferment. Hence the rush to 'investigate' whether fit for it or not. The result is many barren publications, and some disappointed lives.

Research should not be begun too early, nor be pursued to the exclusion of continued general improvement in the science. Professors should have no compunction in stopping the unfit.

The presentment of the results of research in good literary form is a first duty of the investigator; there is too much voiding of mere laboratory notes, and too much prolix writing; an abstract should always be given. Advocate the study of classical papers as models.

In the above notes no mention has been made of the general administrative duties of a professor apart from the teaching of botany.

The following Papers were read:—

1. *Notes on Preserving and Preparing Plants for Museum Purposes. By* H. F. Tagg.

With the object of rendering the preparations educationally more useful, it has been the practice in preparing specimens for the Museum of the Royal Botanic Garden, Edinburgh, to name the different organs by means of labels and pointers attached to the specimen.

A preparation of the kind was exhibited in 1896, but the many inquiries made since regarding the preparation of the specimens prompted a general description of the methods employed along with a statement of the results of some experiments which led to the adoption of these methods.

I. *Methods of Preserving.*—Noticing first the characters of plant specimen we may wish preserved, the separation of these into characters of colour and characters of form coincides with the separation of the methods of preserving into two groups —preserving by drying and preserving by means of liquid media. Drying the plant has proved the only method satisfactory for the preservation of the colours of plants, but fails commonly when applied to the preservation of the natural form.

Liquid preservatives are invaluable for the preservation of the form, but their use involves a sacrifice of the natural colours.

Characters of colour, however, have not as a rule the same morphological importance as have characters of form, so that preserving by drying is rarely resorted to.

Turning to liquid preservatives, all do not preserve the form of plants equally well, and it is important to distinguish those preserving only the form and shape of the separate parts from those preserving, not only the form of the separate organs, but the relationships of the parts to one another also. Expressed concretely, the separate leaves on a twig, their shape, substance, and form, may be well preserved in a given medium; but unless there is also preserved the correct angle at which the leaves stand out from the stem, and their relationships to one another in leaf symmetry, then the preservation of the form of the specimen is of a limited kind. Again, the value from this point of view of any preservative differs somewhat according to the character of the specimens to be preserved. These may be grouped as follows:—

1. Herbaceous plants and organs which in the natural state owe their shape and firmness to the turgescence of the cells more than to special strengthening tissues. Such specimens flag and become soft when that turgescence is lost. For these strong alcohol has given by far the best results. It penetrates quickly and fixes by dehydration the shape and position of the parts before changes due to loss of turgescence occur. Formaline may preserve well the form of the separate parts, but the specimen remains soft and the organs flaccid and drooping.

2. Woody structures, twigs, roots, &c. For these alcohol or an aqueous medium answers equally well. The choice of one or another is determined by a consideration of the ultimate method of exhibition.

3. Succulent plants, succulent fruits, and all bulky specimens containing relatively large quantities of water. Alcohol if employed for these often causes contraction. Formaline or some other aqueous medium is to be preferred, as such penetrate less readily and exert a less energetic attraction for the contained water.

II. *Bleaching.*—Specimens which darken in the alcohol or formaline in which they are preserved are bleached by one or other of the following methods:—(*a*) By immersion in hot or boiling water; (*b*) by means of acid alcohol; (*c*) by the use of bleaching solution (hypochlorite of lime). To prevent as far as possible the darkening in alcohol the specimens are immersed in the preservative as soon as gathered, and when possible exposed at once to direct sunlight.

III. *Mounting.*—The specimens are attached to thin clear glass by means of photoxylin or gelatine, the glass being cut to fit the rectangular vessel in which the specimens are to be exhibited. The back of the vessel is painted a suitable colour, or coloured glass is placed behind the clear glass. Never is the specimen mounted direct upon blue or opal glass, as this renders impossible a change of background should the continued bleaching or darkening of the specimen demand it.

The naming of the parts of the specimen is accomplished as follows:—

1. The parts named are pointed out upon the specimen itself by means of pointers made of thin glass tubes containing colouring matter to render them conspicuous; or

2. A photograph or drawing of the specimen is made, and the names of the parts indicated upon this.

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2. *The Anatomy of* Ceratopteris thalictroides (*Brongniart*). *By* Sybille O. Ford, *Newnham College, Cambridge.*

Ceratopteris thalictroides is the single member of the Parkeriaceæ. It is an annual aquatic fern which occurs in the tropics, either rooted in the mud or floating freely.

The stem is much reduced; sterile as well as fertile leaves are found, both

kinds bearing numerous vegetative buds. The sporangia are scattered on the under side of the fertile leaves, and have no true indusium. The roots in the mature plant arise from the bases of the petioles.

The vascular bundles in the petiole are arranged in two concentric rings, the outer ring being the larger; each individual bundle has a bi-collateral structure.

The stem is polystelic, an outer ring of large steles and an inner group of smaller ones being found. The structure of each bundle is bi-collateral. In young stems the steles are all the same size, the bundles of the first leaves and roots of the young plant being in close connection with those in the stem. The apex of the stem is in the form of a cone with a three-sided apical cell.

The roots have a single stele and several air-passages. The latter arise as splits between cells at a short distance below the three-sided apical cell.

The vegetative buds arise from a single cell. The apical cone is at first very broad, with a three-sided apical cell. In older buds the apex gradually narrows.

Ceratopteris has more strongly marked affinities with the Polypodiaceæ than with any other of the Leptosporangiate ferns. It has slighter affinities with the Marsiliaceæ, and may possibly be intermediate in position between these two orders.

3. *An Apparatus for Studying the Rate of Flow of Solutions in Plant Stems.* *By* Richard J. Anderson, *M.A., M.D., Professor of Natural History, Queen's College, Galway.*

The agents producing the circulation of fluids in plants have been regarded as mainly physical. Osmosis, capillarity, the removal of the fluid by transpiration, chemical changes in the tissues and fluids, and, if some biological factors be added that work out the details of distribution, the agents are well-nigh catalogued. Vital force, if one may use the term, and the change from liquid to gas, and the reversing of this process, have failed to explain the rise of fluid in stems to a height of 200 to 300 feet above the earth. It is therefore of interest to study the conditions under which solutions traverse stems. Two methods of studying the laws of transmission naturally suggest themselves. A water-head may be secured by placing a box at a level sufficiently high to secure the desired pressure and a portion of the stem to be examined connected by a suitable tube to the reservoir; or, imitating the force of transpiration, a suction force set up by means of an aspirating reservoir may be employed. I have used the following method: A rod four feet long is fixed at its centre to a rotating axis. The axis is caused to revolve by a motor (electric preferably). Two stems, as nearly alike as possible, five-eighths of an inch in diameter at the thickest end and eight inches long, are taken and connected each to two small bottles or tubes by caoutchouc. Each bottle has a tube, or second neck, leading to the outer air to maintain the pressure uniform in the bottles. The tube at the stem pole of one of the specimens to be examined and that at the root pole of the other are to be three-quarters filled with weak solution of yellow prussiate of potassium in each case, or a solution of eosin. A solution of perchloride of iron can be used to test the stems in the former case. The two stem specimens are now to be fixed to each side of the rod with the bottles containing the fluids nearest the centre and at the same distance. An axial reservoir may be substituted for the two inner bottles. This has been completed, but I have not yet used it. Stems of Æsculus, Syringa, and Philadelphus have been employed. Solutions pass freely through stems of Syringa, if the bark be retained, when the rod moves at the rate of ninety revolutions per minute. In some experiments the flow from the radical to the apical pole seemed freer. The fluid passed much less freely after removal of the bark. These statements are only provisional. The following interesting questions arise: (*a*) The rate of flow in different stems; (*b*) the comparison of the flow from the radical pole of one stem with the flow from the apical pole of another; (*c*) the comparison of the conducting power of the barked stem with the stem in which the bark is intact; (*d*) the conducting powers of the different

tissues; (*e*) the influence of lateral pressure; (*f*) the difference for different fluids.

4. *On the Anatomy of* Todea, *with an Account of the Geological History of the Osmundaceæ. By* A. C. Seward, *F.R.S., and* Miss Sybille O. Ford.

The anatomical structure of the genus *Osmunda* has been dealt with by several writers, and more particularly by Zanetti in an able paper published in the 'Botanische Zeitung' for 1895, but the other genus of the Osmundaceæ has not received equal attention at the hands of anatomists. Our work, which was undertaken with a view to discover in what respects *Todea* differs from *Osmunda*, includes the examination of *Todea barbara* and *T. superba*, as well as the investigation of series of microtome sections of young plants. The family Osmundaceæ is usually regarded as to some extent intermediate between the Eusporangiate and Leptosporangiate ferns, and in many respects the two genera *Osmunda* and *Todea* are of interest in regard to the phylogeny of the various divisions of the Filicinæ.

The stem of *Todea barbara* is traversed by a single stele composed of xylem groups surrounding a central pith and separated from one another by medullary rays: these groups vary considerably in shape and number at different levels. There may be as few as two or as many as eight xylem strands in one transverse section of the stem, while in *Osmunda regalis* the number is considerably greater. The xylem strands are surrounded by parenchyma, and the sieve-tube zone occupies the same position as in *Osmunda*. This zone, which is continuous in *O. regalis*, is occasionally discontinuous in *Todea* opposite some of the xylem strands. The comparatively large sieve-tubes occur in triangular patches at the outer end of each medullary ray. A characteristic band of tangentially elongated elements succeeds the sieve-tube zone, and this is followed externally by a parenchymatous band, the outermost layer of which constitutes the endodermis. The paper deals with the phyllotaxis of *Todea barbara*, the origin of the leaf-traces, and the gradual alteration in structure which the collateral leaf-trace undergoes as it passes out from the stele of the stem as a horse-shoe shaped strand with one protoxylem group and gradually assumes the form of the broadly U-shaped concentric stele of the petiole with its numerous protoxylem groups. The anatomy of 'seedling' plants of *Todea* is found to agree with that of *Osmunda regalis* plantlets as described by Leclerc du Sablon. As bearing on the questions of relative antiquity and phylogeny of the members of the Filices, we have endeavoured to give an account of the geological history of the Osmundaceæ.

5. *The Glossopteris Flora of Australia. By* E. A. N. Arber, *B.A., Trinity College, Cambridge.*

The *Glossopteris* flora is one of the most remarkable and widely distributed of fossil floras. Typical members, such as the fern-like plants *Glossopteris* and *Gangamopteris*, with the Equisetalean genus *Phyllotheca*, occur in rocks of Permo-Carboniferous age in India, Australia, South Africa, and South America, pointing to the former existence of a southern continent whose flora was for the most part distinct from that of the same age in Europe and North America.

In the Newcastle beds of New South Wales all the typical members of the flora occur without any admixture of northern types (e.g., *Lepidodendron* and *Sigillaria*), as has been recorded from similar beds in South Africa and South America. The flora of the Newcastle rocks is interesting botanically both on account of the wide distribution of the chief members, which show points of identity and unity in type with those of the Lower Gondwana of India and the Permian of Russia, and also from the morphological characters presented by many of the plants themselves. The collection, which forms the subject of these remarks, is in the Geological Museum, Cambridge, and is noteworthy as being one of the earliest (1839–44) formed of fossil plants from the continent of Australia.

TUESDAY, SEPTEMBER 17.

The following Papers were read:—

1. *Heterogenesis in Conifers.* *By* Dr. T. P. LOTSY.

I am going to give a demonstration of a very interesting fact which is called heterogenesis by Korschinsky in a lengthy paper which, originally published in Russian, is now published in German in the last number of 'Flora.'

Heterogenesis, mutation, and spontaneous variation are all words for the same meaning, but the interesting fact about them is that they seem to form at least one way in which new species can arise. I am first going to show you one of the original specimens of *Capsella Heegeri*, kindly given to me by Professor Count Solms-Laubach. You will all have read his paper on this subject in the 'Botanische Zeitung,' and so I have only to remind you that this species was discovered in Lindau by Professor Heeger, in the midst of a large community of *Capsella bursa pastoris*, and there can be very little doubt that this species has suddenly arisen from *Capsella bursa pastoris*. I need not remind you of the fact that *Capsella Heegeri* is true to seed: it reproduces *Capsella Heegeri*, and does not revert to *Capsella bursa pastoris*.

Much more elaborate work, though on the question of the origin of species by means of spontaneous variation, has, as you all know, been done by Hugo de Vries, who is just publishing his important 'Mutationstheorie.'

I need not remind you of his results, especially with *Œnothera Lamarckiana*, which species he cultivated for more than fifteen years, and of which he obtained a number of new species, all suddenly arisen. In his book he calls attention to the fact that a species apparently can exist for very long periods without ever forming new species by means of sudden variations, and that then a period may come during which that species *does* form new species. If this is true, it goes without saying that species which *are* in the period in which they form spontaneous variations should be observed very carefully, and it is therefore that I want to call your attention to two genera of Conifers which are in a period of spontaneous variation, a period in which they do form mutants, to use the terminology of de Vries, which mutants *may* be true to seed. I do not say that they are, as the plants have not yet produced any.

The first species is *Cupressus Lawsoniana.* Among a large number of seedlings at least one plant arose which was very different indeed, as you see here—the *Cupressus Lawsoniana Wisseli*—and among another lot one which was more different yet, the *Cupressus Lawsoniana lycopodioides.* The first one arose in the horticultural establishment of v. d. Wessel in Esse, and the other in that of v. d. Elst in Dedemsraart, both in Holland. I do not hesitate to say that these plants, if their common origin were not known, would be described as true species.

The other plant I want to show you is *Thuja occidentalis Spaethi*, which arose in the same sudden way in the horticultural establishment of Spaeth in Rixdorf, near Berlin.

While I do not want to state that the plants here shown are new species, I yet dare say that a careful observation of these two genera at as many different portions of the world as possible may well be advised, and this is the *sole* object of my communication.

I should think that especially *Cupressus Lawsoniana* is worthy of a good deal of regard in this respect, more so than *Thuja occidentalis* in fact, inasmuch as I feel confident that the new forms of these two species have nothing to do with 'Jugendformen,' while perhaps some retinospora question might step in in the case of *Thuja occidentalis Spaethi.*

2. *On a Primitive Type of Structure in Calamites.* *By* D. H. Scott, *M.A., Ph.D., F.R.S.*

Palæontological research has afforded evidence that the Horsetails and Lycopods—groups now so distinct—had a common origin. The class Sphenophyllales, restricted, so far as we know, to the Palæozoic epoch, combines in an unmistakable manner the characters of Equisetales and Lycopodiales, while at the same time presenting peculiar features of its own. Broadly speaking, it is in the external morphology and in the reproductive structures that the Equisetales are approached, while the anatomy has an evidently Lycopodiaceous character.

The synthetic nature of the Sphenophyllales, indicated clearly enough in the type-genus *Sphenophyllum* itself, comes out still more obviously in the new genus *Cheirostrobus*. Here the general morphology of the strobilus, the form and structure of the sporangiophores and of the sporangia themselves are all of a Calamarian type, while the anatomy of the axis is as clearly Lycopodiaceous in character.

So far nothing has been found to bridge the gulf which separates the anatomy of the Calamarieæ (Palæozoic Equisetales) from that of the Sphenophyllales or the Lycopods. The most ancient known genus of Calamarieæ—*Archæocalamites*—approaches the Sphenophyllales in the superposition of the foliar whorls and in the dichotomous subdivision of the leaves, points on which Professor Potonié, especially, has laid stress. Anatomically, however, according to the researches of Dr. Renault and Count Solms-Laubach, it was an ordinary Calamite, differing in no essential respect from those of the Coal-measures. The stem of *Archæocalamites*, like that of its later allies, had a large pith, surrounded by a ring of collateral vascular bundles, the wood of which, primary as well as secondary, was wholly *centrifugal* in development, the first-formed tracheides lying on the border of the pith, at the points marked by the carinal canals. In *Sphenophyllum*, on the other hand, the whole of the primary wood was *centripetally* developed, and there was no pith. In *Cheirostrobus* the same holds good, except that an insignificant portion of the primary wood may possibly have been added in a centrifugal direction. In Lycopods there may or may not be a pith, but the whole (*Lycopodium*, *Psilotum*, *Lepidodendron*) or the greater part (*Tmesipteris*) of the primary wood is centripetal.

The Calamite which forms the subject of the present communication occurs in the well-known Burntisland beds of the Calciferous Sandstone Series, at the base of the Carboniferous Formation. The material is calcified, and the structure excellently preserved, though the specimens so far discovered are small and fragmentary. Their interest depends on the fact that each vascular bundle possesses a distinct arc of centripetal wood on the side towards the pith. The carinal canals are present, as in an ordinary Calamite, and contain, as usual, the remains of the disorganised protoxylem. They do not, however, as in other Equisetales, form the inner limit of the wood, but xylem of a considerable thickness, and consisting of typical tracheides, extends into the pith on the inner side of the canal, which is thus completely enclosed by the wood. Hence, starting from the spiral tracheides of the protoxylem, there was here a considerable development of xylem in a centripetal as well as in a centrifugal direction. That the organ was a stem, and not a root, is proved, not only by the presence of the carinal canals, but by the occurrence of nodes, at which the outgoing leaf-traces are clearly seen.

This appears to be the first case of centripetal wood observed in a Calamarian stem, and thus serves to furnish a new link between the Palæozoic Equisetales and the Sphenophyllales, and through them with the Lycopods.

The specimens have not as yet supplied any evidence as to the superposition or alternation of the verticils, so we are not at present in a position to determine the genus to which they belonged. Provisionally, until further investigation has cleared up this question, the new stem may bear the name of *Calamites pettycurensis*, from the locality where it occurs.

3. *Remarks upon the Nature of the Stele of Equisetum.* *By* D. T. GWYNNE-VAUGHAN.

The vascular bundles of *Equisetum* are usually compared with those of a monostelic phanerogam both in structural detail and with regard to their course out into the leaf. The following observations made upon the stems of *E. Telmateja*, &c., show that this comparison cannot be satisfactorily maintained.

It was found that of the three strands of xylem present in each bundle of the internode, the carinal strand alone passes out at the node as a leaf-trace. The two lateral strands join on to the xylem of the nodal ring, and in certain species (*E. hiemale*, and better still in *E. giganteum*) they may be traced as externally projecting ridges over the nodal xylem into the internode above. In passing through the node they diverge from one another so that in the internode they are found on the adjacent sides of two different bundles. At the node above they approach each other, and in the next internode they both occur in the same bundle once again. The leaf-trace protoxylem, having entered the bundle, runs downwards for one internode between the two lateral strands: at the node below it divides into two branches which curve to the right and the left in order to fuse with the neighbouring leaf-traces that enter at this node.

So the xylem of the so-called vascular bundle of *Equisetum* consists of three strands, two of which are lateral and cauline, while the median, or carinal, strand is common to both stem and leaf. The fact that only a small portion passes out as a leaf-trace, and not the bundle as a whole, constitutes an essential point of difference between it and the bundle of a phanerogam.

The tracheides in each strand are very few, and consequently it is difficult to determine the direction of their development. However, as regards the leaf-trace and the carinal strand, it appears clear that they are not exarch but endarch, or perhaps slightly mesarch on the adaxial side. The lateral strands, as a whole, are differentiated later than the carinal strand (as might be expected from the close relation of the latter to the leaves), but they do not seem to be a continuation of its centrifugal development. On the contrary, in *E. giganteum*, where as many as ten to fifteen elements are present in each lateral strand, the smallest of them are invariably at the outer extremity, and they gradually increase in size inwards. Longitudinal sections show that the largest tracheides are coarsely reticulate with large pits and very broad bands of thickening between them; in the smaller elements the reticulation becomes finer and more regular, and in the smallest it closely resembles true spiral thickening. To state definitely whether the lateral strands are exarch or not was not possible, because no incompletely differentiated portions of the stem were available; so the question must remain at present undecided, although the mature structure certainly gives a strong impression of centripetal development. Potonié [1] has established a comparison between the secondary vascular tissues of the *Calamariæ* and the *Sphenophyllaceæ* by mentally doing away with the central mass of primary xylem that exists in the latter. By inverting this procedure, and considering it possible that the ancestors of the Equisetums may have possessed a xylem that extended to the centre of the stem, one is led to derive their structure, as it exists at present, from the modification of a stele with a solid central mass of centripetal xylem such as that of *Sphenophyllum*, or of certain Lepidodendreæ. To illustrate the nature of the modifications that such a stele would have to undergo, a series of parallel developments may be pointed out within the latter group (*Lepidodendron Rhodumnense*, *Selaginoides*, *Harcourtii*, *Sigillaria spinosa*, and *Menardi*), in which parenchyma appears in the xylem, and gradually increases in quantity until only an attenuated peripheral ring of xylem remains, which then becomes more or less broken up into separate strands.

It is suggested that the lateral xylem strands in the vascular bundles of the existing Equisetums may perhaps be taken to represent the last remnants of a primitive central mass, and that this would be entirely in agreement with their apparently centripetal development, and in particular with their cauline course.

[1] *Pflanzenpalaeontologie*, p. 205.

4. *Die Silur- und Culm-Flora des Harzes.* *Von* Professor H. POTONIÉ.

5. *On two Malayan 'Myrmecophilous' Ferns.* *By* R. H. YAPP.

Polypodium (Lecanopteris) carnosum (Blume) and Polypodium sinuosum (Wall) are two epiphytic Ferns which occur almost exclusively in the Malay Peninsula and Archipelago.

Their creeping rhizomes are thick and fleshy, the ventral surface closely adhering to the substratum, the dorsal bearing the leaves, which are articulated, upon large conical leaf-cushions. Branching is lateral, and is so frequent in the case of Polypodium carnosum that thick compact masses of interlacing stems are formed, which completely encircle the branches of the tree on which it grows.

The fleshy stems of both Ferns are traversed by an extensive system of hollow spaces, which, like the galleries of Myrmecodia and Hydrophytum, are invariably inhabited by colonies of ants. These 'ant-galleries' are arranged on a perfectly definite plan the details of which differ to some extent in the two Ferns. In both cases, however, there is a single main ventral gallery, which runs in a longitudinal direction through the stem, giving off a lateral gallery to each branch and a dorsal one to each leaf-cushion. The galleries are formed by the breaking down of a large-celled, thin-walled tissue, which in the youngest parts of the stem appears to function as a water-reservoir.

Though undoubtedly closely allied species, these Ferns have been placed by many authorities in different genera. This has been largely on account of the curious position of the sori in Polypodium carnosum. In this Fern, and in one or two of its immediate allies, the sori are borne on marginal lobes, which are completely reflexed upon the upper surface of the frond. This arrangement is possibly connected with spore distribution.

6. *The Vegetation of Mount Ophir.* *By* A. G. TANSLEY.

7. *On Certain Points in the Structure of the Seeds of* Æthiotesta, *Brongn.*, *and* Stephanospermum, *Brongn.* *By* Professor F. W. OLIVER.

The author gave some account of the anatomy of the fossil gymnosperm seed, named by Brongniart *Stephanospermum akenioides*, and of another seed, nearly allied to the foregoing, which he provisionally recognised as *Æthiotesta subglobosa*, Brongn. Attention was drawn to the mantle of tracheal tissue which invests the nucellus in both cases. The possible physiological significance of this tissue was considered, and some suggestions were offered as to the conditions which led to the evolution of the seed in this group. The author expressed the opinion that there was considerable probability that the seed habit was at its origin a xerophilous adaptation.

8. *Natural Surgery in Leaves.* *By* Dr. F. F. BLACKMAN *and* Miss MATTHAEI.

9. *On the Relation between CO_2 Production and Vitality.* *By* Dr. F. F. BLACKMAN *and* Miss MATTHAEI.

9. *On the Strength and Resistance to Pressure of Certain Seeds and Fruits.* *By* G. F. SCOTT ELLIOT, *M.A.*, *B.Sc.*, *F.C.S.*, *F.R.G.S.*

Everyone is familiar with the extraordinary hardness and toughness of many common seeds and fruits, but the writer has failed to discover any definite and detailed account of the amount of weight which such seeds can endure without breaking. The experiments, of which an abstract is given, were generally conducted with a spring balance weighing up to 50 lb., and carefully tested beforehand. Those seeds and fruits which withstood a pressure of 50 lb. were tested with a Wicksteed's single-lever vertical testing machine, which, through the great kindness of Professor J. G. Longbottom, M.E., M.I.M.E., was placed at the author's disposal. In all cases the weight mentioned is that at which the first sign of decided injury could be perceived. Many other seeds and fruits were tried, but a very large number were found unsuitable, through the difficulty of distinguishing the exact moment at which bursting occurred.

	Number examined	Weight in pounds		
		Average	Maximum	Minimum
Fumaria officinalis *L.*, nutlet	4	1·256	1·75	1
'Cardamoms (Native)' seeds	23	7·09	15	8
Mustard seeds	50	4·88	6·75	3·75
Turnip seeds	50	1·635	2·25	1
Cabbage seeds	50	2·16	3·25	1
Viola canina, *L.*, seeds	10	2·1	2·5	1·5
Orange seeds	12	32·08	46	26
Cottonseed seeds	50	19·01	27	11
Pomegranate, Punica granatum, *L.*, seeds	50	14·33	19·5	10
Spindletree, Euonymus europæus, *L.*, seeds	15	4·88	6·5	3·5
Hippophae rhamnoides, *L.*, seeds	—	7·485	10·5	4
Lentils seeds	7	22·428	25	20
Crab's Eyes, Abrus precatorius, *L.*, seeds	7	30·857	44	18
Vicia Cracca, *L.*, seeds	5	13·2	15	12
Sweet Peas seeds	31	32·60	50	16
Calabar Bean, Physostigma venenosum, seed	1	49·50	—	—
Castor oil, Ricinus communis, *L.*	17	17·84	24	9
Hempseed, Cannabis sativa, *L.*	50	4·335	7	2
Hornbeam, Carpinus Betulus, *L.*, nuts	5	27·9	30	25
Pinus stobus seeds	50	3·62	6	2
P. montana seeds	50	1·65	2·75	·5
P. austriaca seeds	50	4·575	6·5	3
P. Pinaster seeds	50	11·156	14	8
P. Cembra seeds	3	22·83	26	20·5
Picea excelsa seeds	50	3·72	5·25	1·5
Yew, Taxus baccata, seeds	3	16	20	13
Carex pendula, Utricle	25	2·18	4·5	2
Wheat (Red Fyfe), Caryopsis	50	20·42	30	12
Wheat (White Fyfe), Caryopsis	56	17·19	26	10
&c. &c.				

In the cases of the following seeds or fruits the breaking weight was over 50 lb. It was therefore not possible to test so large a number as the author would have desired.

	Number examined	Weight in pounds		
		Average	Maximum	Minimum
Brazil nut (nut)	1	5708	—	—
Brazil nut (seeds)	4	94·25	118	80
Sapucaia nuts, Lecythis ollaria, *L.*	3	82·33	100	58
Prunus Padus, *L.*, Cocci	5	80·4	112	48
Plumstones Cocci	3	80·333	99	64
'Peachstones Australian' Cocci	3	177·667	200	153
Cornus mas, *L.*, Cocci	5	82·6	111	60
Manihot Glaziovii seeds	3	117·83	123	114
Hazelnuts, Corylus avellana, *L.*, nuts	7	55·14	80	32
Walnuts Cocci	2	73·5	80	67
Hickory nuts (Carya sp.), Cocci	4	146·75	156	135
Job's Tears, Coix lachryma, Pericarp	4	66·25	90	40

The surface of the fruit or seed in actual contact with the glass at the moment when breaking occurs is generally very small. In order to find the pressure per square inch this surface was measured, and its area calculated in the following manner. An object-glass was painted with a thin layer of black paint, and pressed down upon the seed. That part which was in contact was of course covered by the paint; a piece of white cardboard was then pressed down over the seed under glass, and the area of the stain on the cardboard was calculated by the help of a glass slide ruled in 100ths of an inch. It was found that the pressure in pounds to the square inch was as follows:—

In the Cabbage seed	about 166·2 lb.	to square inch.
„ Hemp seed	„ 433·5 lb.	„
„ Euonymus europæus	„ 244 lb.	„

But of course a square inch of surface is never called into action under natural conditions.

The resisting power depends chiefly upon the shape of the seed and the character of the sclerenchymatous tissue. Generally speaking, the curve of the transverse section of a seed shows an unmistakable resemblance to that of an ordinary stonebridge. On the other hand, both the longitudinal vertical section when the seed is lying a flat surface in a natural position) and the longitudinal horizontal section are generally lanceolate to ovate in shape. These latter curves are probably of great importance, but for a different purpose. It was found, *e.g.*, difficult if not impossible to exert sufficient pressure on the seeds of orange and Abrus precatorius, even when two surfaces of wood were employed to hold them, the shape and the slippery or smooth coats of the seeds resulting in the seed springing out and jumping off. It is possible to make orange seeds, *e.g.*, jump fifteen feet along a flat surface by a slight blow on the end. This peculiar shape will probably enable the seeds to escape from the teeth of an animal, or perhaps facilitate their passage through the alimentary tract. Some of the curves of the seeds employed are illustrated in the paper.

Many special peculiarities of fruits and seeds are important aids to their resisting power. In particular, the ridges on the cremocarps of Myrrhis and Carraway, the peculiar three-cornered nut of Beechmast, the spongy pericarp of Tropæolum, very greatly diminish any danger of injury by pressure from above, as they yield to the pressure and do not break. When seeds are lying on bare earth they are often simply pressed into the earth if any pressure is exerted upon them. Thus, *e.g.*, four seeds of Hemp were placed upon a layer of earth only a quarter of an inch deep, which was spread upon a glass plate. A weight of 56 lb. placed gently on these seeds simply buried them in the earth without injuring them in any way.

WEDNESDAY, SEPTEMBER 18.

The following Papers were read:—

1. *Cuticular Structure of* Euphorbia Abdelkuri. *By* Professor I. BAYLEY BALFOUR, *F.R.S.*

Euphorbia Abdelkuri is an interesting succulent plant which has been brought home from a small island in the vicinity of Sokotra by the Ogilvie-Forbes Expedition. The outer surface of the plant in the fresh condition appears to be covered with a crust which readily cracks off, and on examination this is found to consist of a number of prisms. At first sight these may be taken for some form of mineral incrustation, but they are not of this nature, but are formed by the cuticle of the epidermal cells. This does not form an uninterrupted layer over the epidermis, but the cuticle of each cell is separable from that of the adjacent ones, and the prisms are merely blocks of cuticle, each one belonging to a single cell. This is a construction different from that which is ordinarily met with in plants with thick cuticular layer.

2. *Some Observations upon the Vascular Anatomy of the Cyatheaceæ. By* D. T. GWYNNE-VAUGHAN.

In a number of Dicksonias with creeping or prostrate stems it is shown that the vascular system is solenostelic, the leaf-traces departing as a single strand curved into the form of a horseshoe, with its concavity facing towards the median line of the rhizome—*Dicksonia adiantoides, cicutaria, davallioides, apiifolia,* and *punctiloba.*

In *D. apiifolia* it is found that along the free margin of the leaf-gap there is a considerable increase in the amount of xylem in the solenostele, causing it to project somewhat towards the centre of the stem.

A similar marginal enlargement also occurs in *D. adiantoides*; and here it is continued past the leaf-gap, forming a ridge on the internal surface of the solenostele, running from one leaf-gap margin to another. In the internode this projecting portion of the xylem becomes separated off from the rest and surrounded by a phloëm of its own; however, it remains always included within the same endodermis.

In *Dicksonia rubiginosa* the typical vascular ring is interrupted by gaps other than those due to the leaf-traces, and it may therefore be termed polystelic. In addition there are two or three small accessory steles lying within the vascular ring. Throughout the internode the course of these internal steles is quite free from the vascular ring, but at each node one of them approaches the free margin of the leaf-gap, and completely fuses with it, separating off again after the leaf-gap has become filled up.

Pteris elata var. *Karsteniana* has a typically solenostelic vascular ring, and also possesses internal accessory steles, which behave in a manner quite similar to those of *Dicksonia rubiginosa*; but they are relatively larger, and frequently they all fuse up together so as to form a second, inner, completely closed vascular ring.

It is suggested that the several internal steles and vascular rings that occur in the Saccolomas and in *Matonia pectinata* are also of the same origin and nature as those described above.

The relation of the internal accessory steles in certain Cyatheas to those of the above-mentioned ferns is also discussed.

3. *On the Anatomy of* Danæa *and other Marattiaceæ.* *By* George Brebner.

Various species of the Marattiaceæ were studied for the comparative anatomy of the adult structure, and *Danæa simplicifolia*, Rudge, for the development of the vascular system.

1. Development of the vascular system of *Danæa simplicifolia*, Rudge.

The primary vascular axis is a simple concentric stele. The xylem consists of a central mass of small scalariform tracheids, without any conjunctive parenchyma. The phloëm consists of a layer of small sieve-tubes separated from the xylem by a layer of parenchyma. The pericycle may be absent or only imperfectly represented. There is a definite endodermis, but the constituent cells are not clearly always the innermost ones of the extrastelar parenchyma.

When the cotyledon-trace is about to be given off the xylem of this vascular axis, or 'protostele,' is separated into more or less unequal portions by a layer of parenchyma. The parenchyma increases in amount, and ultimately the cotyledon-trace is separated from the central stele. The cotyledon-trace is collateral. The next few leaf-traces are given off in the same manner, and are likewise collateral. The stele resumes its simple 'protostelic' appearance. Cauline roots occur, but not regularly.

As further leaf-traces depart from, and root-traces join, the vascular axis, the primitive structure is gradually modified, and it may become more or less crescentic, forming an incomplete, or even complete, gamostelic ring. The spaces left by the departure of the leaf-traces now constitute leaf-gaps. The vascular tissue of this stage may be described as a 'siphonostele with leaf-gaps.'

The time of appearance of the first mucilage canal varies. The earliest occurrence noted was after the third leaf-trace had been differentiated.

In one seedling a curious ligament of phloëm was observed, which pursued an oblique course upwards and connected the two horns of a crescentic vascular mass. This strand of phloëm interrupted the course of the central mucilage canal.

At first the leaf-traces are simple and collateral; later they are simple and concentric; still later each trace divides into a pair of strands as it recedes from the axis. At a higher level the leaf-trace consists of a pair of strands each of which takes its departure separately.

A remarkable deviation in the early stages of development was shown by one seedling. A mass of parenchyma early made its appearance in the centre of the xylem, simulating a pith. Careful examination showed that this was due to abortion of the cotyledon and its trace, and exceptionally early preparation for the departure of the three succeeding leaf-traces.

2. Stele of the Marattiaceæ.

The structure of the 'stele,' as seen in transverse section, is singularly uniform in essential histological details throughout the group. It may be said to be of the fern type, but there is no endodermis (*i.e.*, in the case of well-grown plants), and the pericycle is not characteristically present.

The protoxylem is usually endarch—at any rate in the frond—but it may be mesarch.

The protophloëm is internal. This was first demonstrated in the steles of the stem by Miss Shove.[1] It has since been found to be internal in the steles of the frond of two species of *Danæa* and of *Marattia alata*. There can be little doubt that the internal position of the protophloëm is general for the steles of both stem and frond in this group of ferns.

3. Apical growth.

All the fresh evidence obtained while studying the seedlings of *Danæa simplicifolia* is in favour of an initial group, consisting of a few cells, both in stem and root.

[1] *Annals Bot.*, vol. xiv. 1900, p. 497.

4. Roots.

Nothing new has been observed in the roots of the Marattiaceæ. In the roots of *Danæa simplicifolia* there is what might be called a fibrous pith, which is early differentiated, even before the main mass of the xylem has begun to be lignified.

4. *A Chapter of Plant-evolution: Jurassic Floras.* *By* A. C. SEWARD, *F.R.S.*

From the cliffs on the Dorsetshire coast to the moorlands and headlands of East Yorkshire England is traversed diagonally by a band of Jurassic strata, and outlying patches of Jurassic rocks occur in West Somerset, Gloucestershire, Worcestershire, Cumberland, and elsewhere. Sediments of the same age occur also in Sutherlandshire, in the islands of Skye and Mull, and in other parts of Scotland. After the filling up of the inland lakes of the Triassic period, the land gradually subsided and was invaded by a shallow sea in which a thin band of Rhætic sediments was deposited in the British area. The vegetation of this period is represented by the rich floras of Scania, Franconia, and other districts, but in Britain by a few meagre and imperfect records. The rocks formed on the floor of the deeper Liassic sea have afforded several Cycadean fronds and fragments of coniferous trees drifted from neighbouring land. From the estuarine beds intercalated in the series of marine strata of the Oolitic period, an abundant flora has been obtained from Yorkshire and elsewhere. The roofing slates of Stonesfield, described by Plot in his 'Natural History of Oxfordshire' in 1677, have yielded numerous fragments of plants, which may be the relics of the vegetation of an island in the Jurassic sea. From the Oxford clay, Corallian beds, and the Kimeridge clay a comparatively small number of plants have been obtained, while from the overlying Portlandian and Purbeck series the well-known Cycadean stems and the abundance of silicified coniferous wood demonstrate the prominent *rôle* played by gymnospermous plants in the vegetation of the land, which had gradually encroached on the Jurassic ocean. Finally, a rich flora, preserved in the freshwater Wealden sediments, affords a striking proof of the slow change in the character of the vegetation since the Inferior Oolite period.

The chief features in the floras ranging from the Rhætic to the Wealden are briefly described: an attempt is made to determine the dominant types during this long succession of stages in the earth's history, and to estimate the progress of plant-evolution from the close of the Triassic period to the appearance of Angiosperms in rocks of Lower Cretaceous age.

5. *On the Structure and Origin of Jet.* *By* A. C. SEWARD, *F.R.S.*

The hard jet of Whitby appears to have been used in Britain in pre-Roman days; it is alluded to by Caedmon and mentioned in 1350 in the Records of St. Hilda's Abbey. It was formerly extensively mined in the cliffs of the Yorkshire coast, near Whitby and elsewhere; in Eskdale, Danby Dale, and in several of the dales that intersect the East Yorkshire moorlands. The hard jet occurs in the *Ammonites serpentinus* zone of the Upper Lias, frequently in the form of flattened masses or layers, which in rare cases have been found to reach a length of 6 feet. Parkinson in his 'Organic Remains of a Former World' (1811) speaks of jet, in some cases, as pure bituminised vegetable matter, and the majority of writers regard it as having been found as a product of alteration of plant tissues. On the other hand it has been described as 'the result of the segregation of the bitumen' in the intervals of the jet shales, which has sometimes formed pseudomorphs after blocks of wood.[1] The author has recently examined several sections of Yorkshire jet in the British Museum, which he believes demonstrate the origin of this substance from the alteration of coniferous wood and, in part at least, of wood of the Araucarian type.

[1] Tate and Blake, *The Yorkshire Lias*, 1876.

The occurrence of specimens of silicified wood having a covering layer of jet is spoken of by Young in his 'History of Whitby' (1817). Sections cut from specimens which consist in part of petrified wood and in part of jet enable us to trace a gradual passage from well-preserved Araucarian wood to pure jet, which affords little or no evidence of its ligneous origin. The conclusion arrived at is that the Whitby jet owes its origin to the alteration of coniferous wood. The fact that jet frequently occurs in the form of flattened blocks of wood in all probability admits of the natural explanation that the jet has been derived from the wood, the form of which it has assumed, and not that the jet was formed elsewhere and permeated the tissues of the wood as a fluid bitumen.

6. *On Government Planting in the Isle of Man.* *By* G. P. Hughes, *F.R.G.S.*

In August last the author, by permission from Mr. Drinkwater, Crown Lands Receiver in the Isle of Man, inspected, with the head forester, the three plantings of about 1,000 acres commenced by Sir Henry Lock in the year 1882, and added to on a larger scale by his successor, the late Mr. George Calley, when Senior Commissioner in the Department of Crown Lands.

The author was informed in an interview with Mr. Watt, of Carlisle, the contractor who supplied the trees and planters, that the number of trees per acre was 5,000, consisting of oak, Douglas birch, beech, silver, Scotch, and Russian pine, and larch. He employed eighty of his nurserymen from Carlisle, erecting houses and supplying their food on the spot, the cost being 9*l.* per acre, independent of a five-foot stone wall, which must have added one third to the cost.

The land had no surface value, being overgrown by whins, heath, and fern upon shale and impervious rock.

Pruning and weeding from the young trees up to now have been imperative, but over one half of the planted area may be dispensed with, the trees having mastered the situation. On the more exposed parts the trees had suffered from the winds and were dwarfed, but by mutual shelter these trees, ranging to an elevation of mountain 1,000 feet high, have a healthy appearance, showing that they have established roots and promise to become trees. On a level with the lower elevation planted, the Araucaria imbricata and many sub-tropical trees are thriving in the open at Guba Castle, having tree shelter. The writer made the observation that, though shelter, the prospective possession by the Government of forested lands for national emergencies, and the employment of labour for the islanders were leading influences with the Department of Crown Lands, the inhabitants and visitors to the island were much indebted for the climatic and pictorial effects, which add to the amenities of the place as a summer and winter health resort. The thinning of these plantations should shortly commence, and should become a profit to the Government, and a great convenience to the adjoining mines and industries of the island. In the House of Commons the work of the Department of Crown Lands was censured by a few cheese-paring economists, but in the Isle of Man, so far as could be judged, their work was a lesson of sound judgment and exact administration with tenacity of purpose resulting in the assurance of success in the near future and an enduring monument to the patriotic forethought of the eminent Commissioners by whom they were originally planned.

7. *On Spore-formation in Yeasts.* *By* T. Barker.

8. *On a* Diplodia *parasitic on Cacao and on the Sugar Cane.* *By* A. Howard.

9. *On Abnormal Catkins of the Hazel.* *By* Professor F. E. Weiss, *B.Sc.*

SECTION L.—EDUCATIONAL SCIENCE.

PRESIDENT OF THE SECTION—The Right Hon. Sir JOHN E. GORST, K.C., M.P., F.R.S.

THURSDAY, SEPTEMBER 12.

The President delivered the following Address:—

THE invitation of the British Association to preside over the Section of Education, established this year for the first time, has been given to me as a representative of that Government Department which controls the larger, but perhaps not the most efficient, part of the Education of the United Kingdom. The most suitable subject for my opening Address would therefore seem to be the proper function of National Authority, whether central or local, in the education of the people; what is the limit of its obligations; what is the part of Education in which it can lead the way; what is the region in which more powerful influences are at work, and in which it must take care not to hinder their operation; and what are the dangers to real education inseparable from a general national system. I shall avoid questions of the division of functions between Central and Local Authorities, beset with so many bitter controversies, which are political rather than educational.

In the first place, so far as the mass of the youth of a country is concerned, the Public Instructor can only play a secondary part in the most important part of the education of the young—the development of character. The character of a people is by far its most important attribute. It has a great deal more moment in the affairs of the world, and is a much more vital factor in the promotion of national power and influence, and in the spread of Empire, than either physical or mental endowments. The character of each generation depends in the main upon the character of the generation which precedes it; of other causes in operation the effect is comparatively small. A generation may be a little better or a little worse than its forefathers, but it cannot materially differ from them. Improvement and degeneracy are alike slow. The chief causes which produce formation of character are met with in the homes of the people. They are of great variety and mostly too subtle to be controlled. Religious belief, ideas, ineradicable often in maturer life, imbibed from the early instruction of parents, the principles of morality current amongst brothers and sisters and playmates, popular superstitions, national and local prejudices, have a far deeper and more permanent effect upon character than the instruction given in schools or colleges. The teacher, it is true, exercises his influence among the rest. Men and women of all sorts, from university professors to village dames, have stamped some part of their own character upon a large proportion of their disciples. But this is a power that must grow feebler as the number of scholars is increased. In the enormous schools and classes in which the public instruction of the greater part of the children of the people is given the influence on character of the individual teacher is reduced to a minimum. The old village dame might teach her half-dozen children to be kind and brave

and to speak the truth, even if she failed to teach them to read and write. The head master of a school of 2,000, or the teacher of a class of eighty, may be an incomparably better intellectual instructor, but it is impossible for him to exercise much individual influence over the great mass of his scholars.

There are, however, certain children for the formation of whose characters the nation is directly responsible—deserted children, destitute orphans, and children whose parents are criminals or paupers. It is the duty and interest of the nation to provide for the moral education of such children and to supply artificially the influences of individual care and love. The neglect of this obligation is as injurious to the public as to the children. Homes and schools are cheaper than prisons and workhouses. Such a practice as that of permitting dissolute pauper parents to remove their children from public control to spend the summer in vice and beggary at races and fairs, to be returned in the autumn, corrupt in body and mind, to spread disease and vice amongst other children of the State, would not be tolerated in a community intelligently alive to its own interest.

A profound, though indirect and untraceable, influence upon the moral education of a people is exercised by all national administration and legislation. Everything which tends to make the existing generation wiser, happier, or better has an indirect influence on the children. Better dwellings, unadulterated food, recreation grounds, temperance, sanitation, will all affect the character of the rising generation. Regulations for public instruction also influence character. A military spirit may be evoked by the kind of physical instruction given. Brutality may be developed by the sort of punishments enjoined or permitted. But all such causes have a comparatively slight effect upon national character, which is in the main the product for good or evil of more powerful causes which operate, not in the school, but in the home.

For the physical and mental development of children it is now admitted to be the interest and duty of a nation in its collective capacity to see that proper schools are provided in which a certain minimum of primary instruction should be free and compulsory for all, and, further, secondary instruction should be available for those fitted to profit by it. But there are differences of opinion as to the age at which primary instruction should begin and end; as to the subjects it should embrace; as to the qualifications which should entitle to further secondary instruction; and as to how far this should be free or how far paid for by the scholar or his parents.

The age at which school attendance should begin and end is in most countries determined by economic, rather than educational, considerations. Somebody must take charge of infants in order that mothers may be at leisure to work; the demand for child labour empties schools for older children. In the United Kingdom minding babies of three years old and upwards has become a national function. But the infant 'school,' as it is called, should be conducted as a nursery, not as a place of learning. The chief employment of the children should be play. No strain should be put on either muscle or brain. They should be treated with patient kindness, not beaten with canes. It is in the school for older children, to which admission should not be until seven years of age, that the work of serious instruction should begin, and that at first for not more than two or three hours a day. There is no worse mistake than to attempt by too early pressure to cure the evil of too early emancipation from school. Beyond the mechanical accomplishments of reading, writing, and ciphering, essential to any intellectual progress in after life, and dry facts of history and grammar, by which alone they are too often supplemented, it is for the interest of the community that other subjects should be taught. Some effort should be made to develop such faculties of mind and body as are latent in the scholars. The same system is not applicable to all; the school teaching should fit in with the life and surroundings of the child. Variety, not uniformity, should be the rule. Unfortunately the various methods by which children's minds and bodies can be encouraged to grow and expand are still imperfectly understood by many of those who direct or impart public instruction. Examinations are still too often regarded as the best instrument for promoting mental progress; and a large

proportion of the children in schools, both elementary and secondary, are not really educated at all—they are only prepared for examinations. The delicately expanding intellect is crammed with ill-understood and ill-digested facts, because it is the best way of preparing the scholar to undergo an Examination-test. Learning to be used for gaining marks is stored in the mind by a mechanical effort of memory, and is forgotten as soon as the Class-list is published. Intellectual faculties of much greater importance than knowledge, however extensive—as useful to the child whose schooling will cease at fourteen as to the child for whom elementary instruction is but the first step in the ladder of learning—are almost wholly neglected.

The power of research—the art of acquiring information for oneself—on which the most advanced science depends, may by a proper system be cultivated in the youngest scholar of the most elementary school. Curiosity and the desire to find out the reason of things is a natural, and to the ignorant an inconvenient, propensity of almost every child; and there lies before the instructor the whole realm of Nature knowledge in which this propensity can be cultivated. If children in village schools spent less of their early youth in learning mechanically to read, write, and cipher, and more in searching hedgerows and ditch-bottoms for flowers, insects, or other natural objects, their intelligence would be developed by active research, and they would better learn to read, write, and cipher in the end. The faculty of finding out things for oneself is one of the most valuable with which a child can be endowed. There is hardly a calling or business in life in which it is not better to know how to search out information than to possess it already stored. Everything, moreover, which is discovered sticks in the memory and becomes a more secure possession for life than facts lazily imbibed from books and lectures. The faculty of turning to practical uses knowledge possessed might be more cultivated in Primary Schools. It can to a limited extent, but to a limited extent only, be tested by examination. Essays, compositions, problems in mathematics and science, call forth the power of using acquired knowledge. Mere acquisition of knowledge does not necessarily confer the power to make use of it. In actual life a very scanty store of knowledge, coupled with the capacity to apply it adroitly, is of more value than boundless information which the possessor cannot turn to practical use. Some measures should be taken to cultivate taste in Primary Schools. Children are keen admirers. They can be early taught to look for and appreciate what is beautiful in drawing and painting, in poetry and music, in nature, and in life and character. The effect of such learning on manners has been observed from remote antiquity.

Physical exercises are a proper subject for Primary Schools, especially in the artificial life led by children in great cities: both those which develop chests and limbs, atrophied by impure air and the want of healthy games, and those which discipline the hand and the eye—the latter to perceive and appreciate more of what is seen, the former to obey more readily and exactly the impulses of the will. Advantage should be taken of the fact that the children come daily under the observation of a quasi-public officer—the school teacher—to secure them protection, to which they are already entitled by law, against hunger, nakedness, dirt, over-work, and other kinds of cruelty and neglect. Children's ailments and diseases should by periodic inspection be detected: the milder ones, such as sores and chilblains, treated on the spot, the more serious removed to the care of parents or hospitals. Diseases of the eye and all maladies that would impair the capacity of a child to earn its living should in the interest of the community receive prompt attention and the most skilful treatment available. Special schools for children who are crippled, blind, deaf, feeble-minded, or otherwise afflicted should be provided at the public cost, from motives, not of mere philanthropy, but of enlightened self-interest. So far as they improve the capacity of such children they lighten the burden on the community.

I make no apology for having dwelt thus long upon the necessity of a sound system of Primary Instruction: that is the only foundation upon which a national system of advanced education can be built. Without it our efforts and our money will be thrown away. But while primary instruction should be

provided for, and even enforced upon, all, advanced instruction is for the few. It is the interest of the commonwealth at large that every boy and girl showing capacities above the average should be caught and given the best opportunities for developing those capacities. It is not its interest to scatter broadcast a huge system of higher instruction for anyone who chooses to take advantage of it, however unfit to receive it. Such a course is a waste of public resources. The broadcast education is necessarily of an inferior character, as the expenditure which public opinion will at present sanction is only sufficient to provide education of a really high calibre for those whose ultimate attainments will repay the nation for its outlay on their instruction. It is essential that these few should not belong to one class or caste, but should be selected from the mass of the people, and be really the intellectual *élite* of the rising generation. It must, however, be confessed that the arrangements for selecting these choice scholars to whom it is remunerative for the community to give advanced instruction are most imperfect. No 'capacity-catching machine' has been invented which does not perform its function most imperfectly: it lets go some it ought to keep, and it keeps some it ought to let go. Competitive examination, besides spoiling more or less the education of all the competitors, fails to pick out those capable of the greatest development. It is the smartest, who are also sometimes the shallowest, who succeed. 'Whoever thinks in an examination,' an eminent Cambridge tutor used to say, 'is lost.' Nor is position in class obtained by early progress in learning an infallible guide. The dunce of the school sometimes becomes the profound thinker of later life. Some of the most brilliant geniuses in art and science have only developed in manhood. They would never in their boyhood have gained a county scholarship in a competitive examination.

In Primary Schools, while minor varieties are admissible, those, for instance, between town and country, the public instruction provided is mainly of one type; but any useful scheme of higher education must embrace a great variety of methods and courses of instruction. There are roughly at the outset two main divisions of higher education—the one directed to the pursuit of knowledge for its own sake, of which the practical result cannot yet be foreseen, whereby the 'scholar' and the votary of pure science is evolved; the other directed to the acquisition and application of special knowledge by which the craftsman, the designer, and the teacher are produced. The former of these is called Secondary, the latter Technical, Education. Both have numerous subdivisions which trend in special directions.

The varieties of secondary education in the former of these main divisions would have to be determined generally by considerations of age. There must be different courses of study for those whose education is to terminate at sixteen, at eighteen, and at twenty-two or twenty-three. Within each of these divisions, also, there would be at least two types of instruction, mainly according as the student devoted himself chiefly to literature and language, or to mathematics and science. But a general characteristic of all Secondary Schools is that their express aim is much more individual than that of the Primary School: it is to develop the potential capacity of each individual scholar to the highest point, rather than to give, as does the Elementary School, much the same modicum to all. For these reasons it is essential to have small classes, a highly educated staff, and methods of instruction very different from those of the Primary School. In the formation of character the old Secondary Schools of Great Britain have held their own with any in the world. In the rapid development of new Secondary Schools in our cities it is most desirable that this great tradition of British Public School life should be introduced and maintained. It is not unscientific to conclude that the special gift of colonising and administering dependencies, so characteristic of the people of the United Kingdom, is the result of that system of self-government to which every boy in our higher Public Schools is early initiated. But while we boast of the excellence of our higher schools on the character-forming side of their work, we must frankly admit that there is room for improvement on their intellectual side. Classics and mathematics have engrossed too large a share of attention; science, as part of a general liberal education, has been but recently

admitted, and is still imperfectly estimated. Too little time is devoted to it as a school subject: its investigations and its results are misunderstood and undervalued. Tradition in most schools, nearly always literary, alters slowly, and the revolutionary methods of science find all the prejudices of antiquity arrayed against them. Even in scientific studies, lack of time and the obligation to prepare scholars to pass examinations cause too much attention to be paid to theory, and too little to practice, though it is by the latter that the power of original research and of original application of acquired knowledge is best brought out. The acquisition of modern languages was in bygone generations almost entirely neglected. In many schools the time given to this subject is still inadequate, the method of teaching antiquated, the results unsatisfactory. But the absolute necessity of such knowledge in literature, in science, and in commerce is already producing a most salutary reform.

The variety of types of secondary instruction demanded by the various needs and prospects of scholars requires a corresponding variety in the provision of schools. This cannot be settled by a rule-of-three method, as is done in the case of primary instruction. We cannot say that such and such an area being of such a size and of such a population requires so many Secondary Schools of such a capacity. Account must be taken in every place of the respective demands for respective types and grades of secondary education; and existing provision must be considered.

It must not, however, be forgotten that a national system of education has its drawbacks as well as its advantages. The most fatal danger is the tendency of public instruction to suppress or absorb all other agencies, however long established, however excellent their work, and to substitute one uniform mechanical system, destructive alike to present life and future progress. In our country, where there are public schools of the highest repute carried on for the most part under ancient endowments, private schools of individuals and associations, and Universities entirely independent of the Government, there is reasonable hope that with proper care this peril may be escaped. But its existence should never be forgotten. Universal efficiency in all establishments that profess to educate any section of the people may properly be required; but the variety, the individuality, and the independence of schools of every sort, primary and secondary, higher and lower, should be jealously guarded. Such attributes once lost can never be restored.

There still remains for our consideration the second division of Higher Education, viz., the applied or technological side. It is in this branch of Education that Great Britain is most behind the rest of the world; and the nation in its efforts to make up the lost ground fails to recognise the fact that real technical instruction (of whatever type) cannot possibly be assimilated by a student unless a proper foundation has been laid previously by a thorough grounding of elementary and secondary instruction. Our efforts at reform are abrupt and disconnected. A panic from time to time sets in as to our backwardness in some particular branch of commerce or industry. There is a sudden rush to supply the need. Classes and schools spring up like mushrooms, which profess to give instruction in the lacking branch of applied science to scholars who have no elementary knowledge of the particular science, and whose general capacities have never been sufficiently developed. Students are invited to climb the higher rungs of the ladder of learning who have never trod the lower. But science cannot be taught to those who cannot read, nor commerce to those who cannot write. A few elementary lessons in shorthand and book-keeping will not fit the British people to compete with the commercial enterprise of Germany. Such sudden and random attempts to reform our system of technical education are time and money wasted. There are grades and types in technological instruction, and progress can only be slow. It is useless to accept in the higher branches a student who does not come with a solid foundation on which to build. In such institutions as the Polytechnics at Zurich and Charlottenburg we find the students exclusively drawn from those who have already completed the highest branches of general education; in this country there is hardly a single institution where this could be said of more than

a mere fraction of its students. The middle grades of technological instruction suffer from a similar defect. Boys are entered at technical institutions whose only previous instruction has been at elementary schools and evening classes; whose intellectual faculties have not been developed to the requisite point; and who have to be retaught the elements to fit them for the higher instruction. In fact there is no scientific conception of what this kind of instruction is to accomplish, and of its proper and necessary basis of general education.

Yet this is just the division of Higher Education in which Public Authority finds a field for its operations practically unoccupied. There are no ancient institutions which there is risk of supplanting. The variety of the subject itself is such that there is little danger of sinking into a uniform and mechanical system. What is required is first a scientific, well-thought-out plan and then its prompt and effective execution. A proper provision of the various grades and types of technological instruction should be organised in every place. The aim of each institution should be clear; and the intellectual equipment essential for admission to each should be laid down and enforced. The principles of true economy, from the national point of view, must not be lost sight of. Provision can only be made (since it must be of the highest type to be of the slightest use) for those really qualified to profit by it to the point of benefiting the community. Evening classes with no standard for admission and no test of efficiency may be valuable from a social point of view as providing innocent occupation and amusement, but they are doing little to raise the technical capacity of the nation. So far from 'developing a popular demand for higher instruction' they may be preventing its proper growth by perpetuating the popular misconception of what real technical instruction is, and of the sacrifices we must make if our people are to compete on equal terms with other nations in the commerce of the world. The progress made under such a system would at first be slow; the number of students would be few until improvements in our systems of primary and secondary instruction afforded more abundant material on which to work; but our foundation would be on a rock, and every addition we were able to make would be permanent, and contribute to the final completion of the edifice.

It is the special function of the British Association to inculcate 'a scientific view of things' in every department of life. There is nothing in which scientific conception is at the present moment more urgently required than in National Education; and there is this peculiar difficulty in the problem, that any attempt to construct a national system inevitably arouses burning controversies, economical, religious, and political. It is only a society like this, with an established philosophical character, that can afford to reduce popular cries about education (which ignore what education really is, and perpetuate the absurdity that it consists in attending classes, passing examinations, and obtaining certificates) to their true proportions. If this Association could succeed in establishing in the minds of the people a scientific conception of a National Education System, such as has already been evolved by most of the nations of Europe, the States of America, and our own Colonies, it would have rendered a service of inestimable value to the British nation.

The following Papers were read:—

1. *The Organisation of Secondary Education.* *By* Sir Henry E. Roscoe, *F.R.S.*

2. *The Mechanism for Education in Scotland.* *By* John Adams.

In Scotland the School Board system is universal. The whole country is divided up into School Board areas. It is true that there are a number of Voluntary schools throughout the country, mainly connected with the Episcopalian

and Roman Catholic Churches, but these make up less than twelve per cent. of the whole.

Between the years of five and fourteen education is compulsory, but exemption may be obtained in whole or in part on passing certain examinations.

In Scotland the line of division between primary and secondary schools is not nearly so clear as in England. 'Public School' means in Scotland any school, whether primary or secondary, that is under the management of a School Board. By the Education (Scotland) Act, 1872, eleven schools were scheduled as Higher Class Public Schools. There are now thirty such schools, all of them placed entirely under the control of School Boards 'with a view to promote the higher education of the country.' The fundamental difference between these and all the other public schools of Scotland is that the Higher Class Schools are debarred from earning the annual parliamentary grant. All the other public schools are usually referred to as 'grant-earning.' Voluntary schools are also grant-earning, since they receive all the grants of the ordinary public schools, with the addition of an annual grant of three shillings per pupil in average attendance.

The Higher Class Public Schools are supported by contributions from the municipal authorities of the district, according to ancient custom, by certain endowments varying with each case, by fees, and by the rates. If need be, the School Board may charge all the expenses of a Higher Class School on the rates, except the salaries of teachers. The Board has great freedom in dealing with the Higher Class Schools. It determines the qualifications to be demanded from the teachers, and has the power of causing candidates for the post of teacher to be examined. This power is rarely, if ever, exercised. The qualification demanded is usually the possession of a University degree. These schools are examined annually.

The grant-earning schools are subject to many more restrictions. Only duly certificated teachers can be employed, and certain rigid rules about registration, accommodation, time-tables, religious instruction, have to be attended to. The annual grant depends upon the report made by an inspector representing the Scotch Education Department. As to the subjects studied, however, there is no rigid line marking off the grant-earning schools from the others. The tradition of the Scottish Parish School is that each school is fit to prepare a lad to go direct from school to university, and in the north-east of Scotland—thanks to the Dick and Milne Bequests—the tradition is justified to this day. Speaking broadly, however, the grant-earning school contents itself with efficient elementary work. The Merit Certificate represents the attainments aimed at in the elementary public schools. To gain this certificate the pupil must give evidence of a thorough grounding in reading, writing, and arithmetic, and must have a good working knowledge of elementary English, nature knowledge, and the more practical aspects of geography, with some general acquaintance with British history. But wherever there is the least desire for higher education, arrangements are made to carry the pupil beyond the Merit Certificate stage. This may be done in either of two ways: (1) An Advanced Department may be formed, in which pupils who have gained the Merit Certificate may be taught, in classes of not more than forty, the subjects of English, geography, history, arithmetic, and as a rule drawing; and in addition such of the following subjects as are found suitable under the circumstances: languages, mathematics, science. (2) A Higher Grade Department may be established, or a whole school in a district may be set apart as a Higher Grade School. In these schools or departments there must be a duly qualified teacher for every thirty or fewer pupils on the roll, and there must be a well-defined course of instruction approved by the Department, and extending over not less than three years. The education in such schools may be predominantly scientific or predominantly commercial, or they may give a course specially adapted for girls, or for any special class of pupils. Considerable latitude is permitted in proposing courses of study, even classical subjects being permitted as a subordinate part of a course that otherwise satisfies the department. But stringent conditions are laid down to prevent scrappiness.

As matters stand, Advanced Departments and Higher Grade Schools are meant

to be ends in themselves. The pupil when finished with them is regarded as having completed his education. The Higher Class Schools seek to prepare their pupils for the University, though naturally a large proportion of their pupils do not carry on their studies beyond the school. The Leaving Certificate Examination holds the same relation to the Higher Class School that the Merit Certificate holds to the Elementary Grant-earning School. In the meantime the subjects of the Leaving Certificate Examination may be taken singly, but certificates are now being issued also in groups, this grouping implying school attendance as well as mere passing of examinations. Subject for subject these Leaving Certificates are accepted by the Universities as exempting from the corresponding subjects in the University Preliminary Examination. Probably in a few years the Leaving Certificate will practically take the place of the University Preliminary Examination.

Besides the Higher Class Public Schools there are the usual endowed schools and company schools, which exceed in number and rival in efficiency the School Board schools. By the Technical Schools (Scotland) Act, 1887, and subsequent amendments, School Boards have the power of founding and maintaining at the expense of the ratepayers technical schools in subjects needed in their districts.

There are thirty-nine Secondary Education Committees, each representing a county, a burgh, or a parish—mostly counties—whose function is to distribute certain moneys that are set apart by the Government each year for the purpose of assisting secondary education. The Scotch Education Department is represented on each of these Committees by one of His Majesty's Inspectors of Schools. Those Committees wield a very important influence by the methods in which they allocate the funds. The County Councils, too, have the power of aiding secondary or technical education out of certain grants made to them for various local purposes. There is a general desire for some unification of all the different authorities that thus influence, sometimes in opposite ways, the course of Secondary Education in Scotland. Some recommend the handing over of Education to the County Councils, to be dealt with along with the other matters of local government; others desire an extension of the School Board area, leaving the control of all educational matters, whether primary or secondary, in the hands of School Boards representing counties or other large areas.

3. *Organisation of Education in Glasgow.* *By* Dr. W. JACKS.

4. *The Training of the Practical Man.*
By Dr. JOHN G. KERR, *Head Master of Allan Glen's School, Glasgow.*

The author quoted Carlyle to the effect that 'the grand result of schooling was a mind with just vision to discern, with free force to do,' and considered whether the system of education at present provided was in the direction of encouraging that independent thought and action which marked the practical man in the best sense. The kindergarten and the primary school, in Dr. Kerr's opinion, were now offering a liberal discipline, and the conditions under which the merit certificate was obtained secured breadth of general and practical training. That there were in the Glasgow area last year over 20,000 enrolments for special courses of instruction in evening continuation schools was fair proof of the efficiency of the primary school system. Considering those pupils who passed into secondary schools and the average duration of secondary school life, Dr. Kerr pointed out that the superiority of Germany was to some extent due to its military system and to the operation of 'the certificate for one year's military service,' for that certificate not only reduced military service, but qualified for businesses, opened the way to higher studies, and stamped the educated classes. If our secondary school work was to grow there must be inducements to keep promising pupils at school. The agencies which were at present concerned with the preliminary training of those who were to be engaged in industries and

manufactures were higher grade schools and schools of science. The methods followed were explained, and Dr. Kerr declared that most valuable results might be anticipated from the highly practical training they provided. He argued in favour of the institution of maintenance scholarships, which would merely be payments during the period of preparation for capable citizenship, and he contended that the able youth who had to face such a trade as engineering should not be required to work through five years' apprenticeship in the shops if the school training which he had received justified a reduction. With increased school training the genuinely capable youth would make the very most of his workshop experiences, would more easily find his way to higher positions, and be likely to do better national service than could be expected from the less educated youth who had been hurried into hard manual work before a basis of knowledge had been laid or good intellectual habits acquired.

Dr. Kerr anticipated no serious objections to diminished apprenticeship from the trades unions, and the capitalist employer would not be altogether influenced in his attitude by the profitableness of apprenticeship labour. It was the case that many apprentices of ability were discouraged, and it was true that many other promising youths of scientific and mechanical turn kept clear of apprenticeship. But Britain could not afford to let capacity go to waste, and accordingly every effort should be made to discover and train for industries youths of first-class brain-power. France, in applying prudent and skilful methods of eliminating the unfit from point to point in the higher practical schools, had set an example which might be followed with profit.

FRIDAY, SEPTEMBER 13.

The following Papers were read:—

1. *The Future Work of the Section.* *By* Professor H. E. ARMSTRONG, *F.R.S.*

2. *The Experimental Method of Teaching.* *By* Professor L. C. MIALL, *F.R.S.*

3. *On the Scope of the Science of Education.* *By* Professor H. L. WITHERS.

At the outset of the work of the new Section of Educational Science it is of extreme importance that we should come to some working agreement about its scope. There is grave risk of our being overwhelmed by a multitude of interesting problems, some of which cannot properly be attacked before we have settled our procedure and arranged our topics in some sort of order of priority and proportional importance. In that case our discussions are likely to be no more convincing than the debates of the many scores of clubs and societies which are already pouring out an endless stream of papers and treatises on educational subjects. We must begin with the matters which are most fundamental and central, and leave for a while those which are subordinate and marginal.

We start with the claim that there is such a study as the science of education. A study does not become a science until it is systematic, orderly, and continuous; until the field of its investigations is marked out; and until the terms which it uses are defined with some precision. Until this point is reached everything remains a matter of opinion and prejudice, and no genuine advance in thought is possible. We must admit that this point has not yet been reached in the British study of

education, and it is the difficult and responsible duty of this Section to attempt to place our study upon an objective and truly scientific basis.

The necessity for a scientific study of education has been brought home to the British Association by the force of events. Discussions have arisen from time to time in the various Sections as to the true methods of teaching different subjects of science. In the Section of Chemistry much valuable work has been done, under the lead of Professor Armstrong, by means of a committee working in co-operation with practical teachers. Much also has been accomplished by the Geographical Section for the reform of methods of instruction in geography.

There can be no doubt that this plan of treating education in separate departments makes an admirable introduction to further investigation, but it is clearly inadequate in scope and faulty in method unless it be carried into a much wider field. To begin with, the different Sections of the Association only touch a small part of the whole sphere of education. They leave out almost all that is implied in the training of the character and the feelings, the cultivation of the power of expression through language, and the enlargement of sympathy that comes through the study of literature. Secondly, such a method of dealing with single subjects by themselves is unsound both in logic and in practice. The practical schoolmaster is attacked by specialists in an endless number of subjects, each one of whom demands that his own speciality shall be taught, and taught thoroughly. The schoolmaster cannot possibly teach them all; he must make some selection among them. On what rational grounds is he to do this? His school time-table shows his practical answer; he divides the twenty-five hours a week which he has to distribute among the different parts of the curriculum in certain proportions, giving, let us say, five hours to mathematics, two to history, five to the study of the mother tongue and its literature, and so forth. If he has any well-considered and intelligible account to give of his time-table, that account must be rendered in the terms of some theory of the comparative importance of the various subjects to his pupils. This implies some conception of an ordered system of knowledge as a whole, quite apart from the individual claims of specialists. This theory of the curriculum is an important part of the science of education. Again, if we turn to the question of methods of instruction we cannot solve the problems which they raise by referring to the different subjects in isolation. For instance, are we to teach geometry demonstratively in the method of Euclid, or concretely and through physical applications? We can get no sure answer by appealing to the mathematical specialists. They will tell us that it depends what our object is in teaching geometry; what mental powers we wish to train; what later applications we intend to make of the geometrical faculty when acquired. That is, we find ourselves referred partly to a consideration of the total aim and purpose of our education and partly to its technical bearings. And these are not mathematical considerations at all. Similarly, if we are asked how we are to teach a language, let us say French, we cannot give a satisfactory answer in terms of French linguistic science alone. We must reply that it depends upon our *purpose* in teaching French, whether, that is, we desire to make it a key to knowledge of one of the foremost literatures in Europe, or whether we desire to give a power to conduct commercial correspondence in French, or whether we aim at both of these ends and many others that might be named. There is no such thing as a method in the abstract. A method is a means to an end, and varies indefinitely in relation to that end.

It is clear, therefore, that the science of teaching is not the same thing as the teaching of science. The study which belongs to Section L must be, in a sense, independent of the subjects studied in the other Sections, although, in another sense, it is closely bound up with them. The great work which the Section can do is to introduce some kind of order into the confusion which rages at present in educational controversy. It can achieve this only by simplifying and concentrating its field of work, by defining its scope, and by aiming at an orderly and systematic treatment of its main topics.

We may best arrive at an idea of the scope of educational science by considering the following questions: What is it that the educator should study and practise

apart altogether from the two or three departments of knowledge in which he may happen to be a specialist? What are the chief topics in regard to which he ought to seek after clear ideas and sound action?

We must begin, must we not? with a rough working definition of education itself. Education is a living process in virtue of which the partly developed young of the human species are adjusted by nourishment and exercise to the environment in which, when fully grown, they will have to continue to live. That environment is partly physical and partly human.

Healthy activity in relation to nature and man may serve as a working definition of our end, and in order to obtain this for children we must aim at clear ideas about the following points:—

(*a*) Physical health in the home and in school.

(*b*) A sound correspondence, implying health of brain and nerves, between the mind of the child and the natural phenomena which surround it, and which form the background of human life.

(*c*) A cultivation in the child of human sympathy with the community of which he is to form a part; a power to express that sympathy in clear language; an understanding of human nature and of the art and literature in which that human nature has most characteristically embodied itself; some knowlege of human history and of the gradual process by which mankind has attained to the position in which we find it. All this must be accompanied by constant habituation to healthy activity with other human beings in the social relations of home and school.

These appear to be the indispensable conditions of adjustment of the growing child to his environment. To aid that adjustment it is evident that the educator must clear up his ideas on many points. Of these the most important and most central might be specified as follows:—

(i.) The hygiene of human growth, with special reference to the healthy functions of growing brains and nerves.

(ii.) The theory of the curriculum, which must include a consideration of the comparative value for growing children of different subjects of study, and of the order and mutual relation in which these subjects should be presented to the adolescent mind.

(iii.) The theory of method, which must embrace a study of the conditions under which the maximum of mental and moral activity can be attained without overstrain. It will therefore comprise an investigation into the symptoms and causes of brain fatigue. It will consider the circumstances under which the interest and self-activity of children are best roused and maintained. It will require a series of practical experiments conducted by trained observers under the ordinary conditions of school life.

(iv.) The study of the conditions under which desirable qualities of character are produced, such, for instance, as courage, kindness, initiative, firmness of will, and the like. Under this head would come the scientific study of play, of imitation, of the influence of suggestion, and so forth, as well as of the influence of the school community and school institutions.

In these four topics, which may be summed up as physical and mental hygiene, the theory of the curriculum, the theory of method, and the theory of character, might be found a rough working scheme of the scope of educational science. When we have arrived at some sort of agreement upon them we shall have to consider the forms of administration and organisation most likely to foster desirable conditions. For this we shall need a comparative study of educational institutions, including those of foreign nations and those which have existed in the past. After this we may proceed to the corollaries and riders of our main topics, such, for instance, as the problem of how best to prepare children for particular trades and professions, such as engineering or law, and in especial how to train those who are going to be educators, for the effective practice of the scientific principles of their profession.

4. *Some Considerations bearing on the Practical Study of Educational Science. By* P. A. BARNETT, *M.A.*

SATURDAY, SEPTEMBER 14.

A Joint Discussion with Section A on the Teaching of Mathematics, opened by Professor JOHN PERRY, *F.R.S.*[1]

MONDAY, SEPTEMBER 16.

1. *Joint Discussion with Section K on the Teaching of Botany.*
See p. 843.

2. *Joint Discussion with Section F on Commercial Education, opened by* Mr. L. L. PRICE.—See p. 751.

3. *Report on the Teaching of Science in Elementary Schools.*
See Reports, p. 458.

TUESDAY, SEPTEMBER 17.

The following Papers were read:—

The Influence of Universities and Examining Bodies upon the Work of Elementary Schools. By the Right Reverend JOHN PERCIVAL, *D.D., Lord Bishop of Hereford.*—See Reports, p. 448.

2. *Liberal Education for Boys leaving School at Sixteen or Seventeen. By* H. W. EVE, *M.A.*

It is generally admitted that a complete classical education under the best conditions, properly supplemented by other subjects, is thoroughly good of its kind. For those who have not adequate time the problem of devising a good curriculum is difficult. It is necessary to guard, on the one hand, against a curriculum too exclusively practical, and on the other against the waste of time on a half-finished classical education, generally including no Greek. Too often the result is that time and energy are spent on gaining a very imperfect knowledge of Latin, which might have been more profitably devoted to other subjects. The Latin learnt at school is never kept up: it contributes but little to the formation of intellectual tastes, so necessary as an antidote to trivial and vulgar pursuits. What is really wanted is a secondary education at once practical and liberal, and that in a world much changed within the lifetime of men not yet old. Science must fill an important place in such an education: not only must

[1] Published with an account of the Discussion which followed the reading of the Paper, Macmillan & Co., London, 1901.

some familiarity with scientific method be acquired, but also a good deal of that scientific knowledge which is essential for intelligent general reading. Add to the time required for mathematics and science what is needed for English, history, and geography, and two modern languages, and but little time is left for Latin. German, too much neglected in English schools, is essential both on practical and on general grounds, and should take the place of Latin. Nor would there be any appreciable loss in point of discipline and training. Modern languages, though easier than the classical languages, present quite enough difficulties for the average boy, and he has at the end of his course something to show for his efforts. Much depends on effective scholarly teaching and on the selection of reading-books requiring sustained thought.

INDEX.

References to reports and papers printed in extenso *are given in Italics.*
*An Asterisk * indicates that the title only of the communication is given.*
The mark † indicates the same, but a reference is given to the Journal or Newspaper where the paper is published in extenso.

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LODGE, Principal O. J., F.R.S.
MACALISTER, Professor A. F.R.S.
MACMAHON, Major P. A., F.R.S.
MARR, J. E., Esq., F.R.S.
PERKIN, Professor W. H., F.R.S.
PERRY, Professor JOHN, F.R.S.
PREECE, Sir W. H., K.C.B., F.R.S.
PRICE, L. L., Esq., M.A.
SEWARD, A. C., Esq., F.R.S.
SOLLAS, Professor W. J., F.R.S.
TILDEN, Professor W. A., F.R.S.
TYLOR, Professor E. B., F.R.S.
WOLFE-BARRY, Sir JOHN, K.C.B., F.R.S.

EX-OFFICIO MEMBERS OF THE COUNCIL.

The Trustees, the President and President Elect, the Presidents of former years, the Vice-Presidents and Vice-Presidents Elect, the General and Assistant General Secretaries for the present and former years, the Secretary, the General Treasurers for the present and former years, and the Local Treasurer and Secretaries for the ensuing Meeting.

TRUSTEES (PERMANENT).

The Right Hon. Lord AVEBURY, D.C.L., LL.D., F.R.S., F.L.S.
The Right Hon. Lord RAYLEIGH, M.A., D.C.L., LL.D., F.R.S., F.R.A.S.
Professor A. W. RÜCKER, M.A., D.Sc., Sec.R.S.

PRESIDENTS OF FORMER YEARS.

Sir Joseph D. Hooker, G.C.S.I.
Sir George Gabriel Stokes, Bart., F.R.S.
Lord Kelvin, G.C.V.O., F.R.S.
Prof. A. W. Williamson, F.R.S.
Lord Avebury, D.C.L., F.R.S.
Lord Rayleigh, D.C.L., F.R.S.
Sir H. E. Roscoe, D.C.L., F.R.S.
Sir F. J. Bramwell, Bart., F.R.S.
Sir F. A. Abel, Bart., K.C.B., F.R.S.
Sir Wm. Huggins, K.C.B., Pres.R.S.
Sir Archibald Geikie, LL.D., F.R.S.
Prof. Sir J. S. Burdon Sanderson, Bart., F.R.S.
The Marquis of Salisbury, K.G., F.R.S.
Lord Lister, D.C.L., F.R.S.
Sir John Evans, K.C.B., F.R.S.
Sir William Crookes, F.R.S.
Sir Michael Foster, K.C.B., M.P., F.R.S.
Sir W. Turner, K.C.B., F.R.S.

GENERAL OFFICERS OF FORMER YEARS.

F. Galton, Esq., D.C.L., F.R.S.
Prof. Sir Michael Foster, K.C.B., M.P., Sec. R.S.
G. Griffith, Esq., M.A.
P. L. Sclater, Esq., Ph.D., F.R.S.
Prof. T. G. Bonney, D.Sc., F.R.S.
Prof. A. W. Williamson, F.R.S.
A. Vernon Harcourt, Esq., F.R.S.
Prof. A. W. Rücker, D.Sc., Sec.R.S.
Prof. E. A. Schäfer, F.R.S.

AUDITORS.

E. W. Brabrook, Esq., C.B. | L. L. Price, Esq., M.A.

LIST OF MEMBERS

OF THE

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

1901.

* indicates Life Members entitled to the Annual Report.
§ indicates Annual Subscribers entitled to the Annual Report for 1901.
§§ indicates Annual Subscribers who will be entitled to the Annual Report if their Subscriptions are paid by December 31, 1902.
‡ indicates Subscribers not entitled to the Annual Report.
Names without any mark before them are Life Members, elected before 1845, not entitled to the Annual Report.
Names of Members of the GENERAL COMMITTEE are printed in SMALL CAPITALS.
Names of Members whose addresses are incomplete or not known are in *italics*.

Notice of changes of residence should be sent to the Assistant General Secretary, G. Griffith, Esq., Burlington House, W.

Year of Election.

1887. *ABBE, Professor CLEVELAND. Weather Bureau, Department of Agriculture, Washington, U.S.A.
1897. ‡Abbott, A. H. Brockville, Ontario, Canada.
1898. §Abbott, George, M.R.C.S. 33 Upper Grosvenor-road, Tunbridge Wells.
1881. *Abbott, R. T. G. Whitley House, Malton.
1887. ‡Abbott, T. C. Eastleigh, Queen's-road, Bowdon, Cheshire.
1863. *ABEL, Sir FREDERICK AUGUSTUS, Bart., G.C.V.O., K.C.B., D.C.L., D.Sc., F.R.S., V.P.C.S. (PRESIDENT, 1890; Council 1875–82; Pres. B. 1877), President of the Government Committee on Explosives. 2 Whitehall-court, S.W.
1902. §§ABERCORN, the Duke of, K.G. (VICE-PRESIDENT, 1902). Barons Court, Ireland.
1885. *ABERDEEN, The Right Hon. the Earl of, G.C.M.G., LL.D. Haddo House, Aberdeen.
1885. ‡Aberdeen, The Countess of. Haddo House, Aberdeen.
1885. ‡Abernethy, James W. 2 Rubislaw-place, Aberdeen.
1873. *ABNEY, Captain Sir W. DE W., K.C.B., D.C.L., F.R.S., F.R.A.S. (Pres. A, 1889; Council, 1884–89). Rathmore Lodge, Bolton-gardens South, Earl's Court, S.W.

Year of Election.

1886. ‡Abraham, Harry. 147 High-street, Southampton.
1884. ‡Acheson, George. Collegiate Institute, Toronto, Canada.
1873. ‡Ackroyd, Samuel. Greaves-street, Little Horton, Bradford, Yorkshire.
1900. §Ackroyd, William, Borough Laboratory, Crossley Street, Halifax.
1882. *Acland, Alfred Dyke. 38 Pont-street, Chelsea, S.W.
1869. ‡Acland, Sir C. T. Dyke, Bart., M.A. Killerton, Exeter.
1877. *Acland, Captain Francis E. Dyke, R.A. Woodmansterne Rectory, Banstead, Surrey.
1873. *Acland, Rev. H. D., M.A. Luccombe Rectory, Taunton.
1894. *Acland, Henry Dyke, F.G.S. The Old Bank, Great Malvern.
1877. *Acland, Theodore Dyke, M.D. 19 Bryanston Square, W.
1898. ‡Acworth, W. M. 47 St. George's-square, S.W.
1901. §Adam, J. M. 15 Walmer Crescent, Glasgow.
1887. ‡Adami, J. G., M.A., M.D., Professor of Pathology in the University, Montreal, Canada.
1892. ‡Adams, David. Rockville, North Queensferry.
1884. ‡Adams, Frank Donovan. Geological Survey, Ottawa, Canada.
1901. §Adams, John. 12 Holyrood Crescent, Glasgow.
1871. ‡Adams, John R. 2 Nutley-terrace, Hampstead, N.W.
1879. *Adams, Rev. Thomas, M.A., D.C.L. (Local Sec. 1881). 4 Avenue Terrace, Paignton, South Devon.
1869. *Adams, William Grylls, M.A., D.Sc., F.R.S., F.G.S., F.C.P.S. (Pres. A, 1880; Council 1878–85), Professor of Natural Philosophy and Astronomy in King's College, London. 43 Campden Hill-square, W.
1901. §Adamson, P. 11 Fairlie Park Drive, Glasgow.
1879. ‡Adamson, Robert, M.A., LL.D., Professor of Logic in the University of Glasgow.
1896. ‡Adamson, W. Sunnyside House, Prince's Park, Liverpool.
1898. §Addison, William L. T. Byng Inlet, Ontario, Canada.
1890. ‡Addyman, James Wilson, B.A. Belmont, Starbeck, Harrogate.
1890. ‡Adeney, W. E., B.Sc., F.C.S. Royal University of Ireland, Earlsfort-terrace, Dublin.
1899. §Adie, R. H., M.A., B.Sc. 8 Richmond-road, Cambridge.
1883. ‡Adshead, Samuel. School of Science, Macclesfield.
1884. ‡Agnew, Cornelius R. 266 Maddison-avenue, New York, U.S.A.
1864. *Ainsworth, David. The Flosh, Cleator, Carnforth.
1871. *Ainsworth, John Stirling. Harecroft, Gosforth, Cumberland.
1871. ‡Ainsworth, William M. The Flosh, Cleator, Carnforth.
1895. *Airy, Hubert, M.D. Stoke House, Woodbridge, Suffolk.
1891. *Aisbitt, M. W. Mountstuart-square, Cardiff.
1871. §Aitken, John, F.R.S., F.R.S.E. Ardenlea, Falkirk, N.B.
1901. §Aitken, Thomas. County Buildings, Cupar, Fife.
1898. ‡Akers-Douglas, Right Hon. A., M.P. 106 Mount-street, W.
1884. *Alabaster, H. Milton, Grange Road, Sutton, Surrey.
1886. *Albright, G. S. The Elms. Edgbaston, Birmingham.
1900. §Aldren, Francis J., M.A. The Lizans, Malvern Link.
1896. §Aldridge, J. G. W., Assoc.M.Inst.C.E. 9 Victoria-street, Westminster, S.W.
1894. ‡Alexander, A. W. Blackwall Lodge, Halifax.
1891. ‡Alexander, D. T. Dynas Powis, Cardiff.
1883. ‡Alexander, George. Kildare-street Club, Dublin.
1888. *Alexander, Patrick Y. Experimental Works, Bath.
1896. ‡Alexander, William. 45 Highfield South, Rockferry, Cheshire.
1891. *Alford, Charles J., F.G.S. 15 Great St. Helens, E.C.
1883. ‡Alger, Miss Ethel. The Manor House, Stoke Damerel, South Devon.

Year of Election.

1883. ‡Alger, W. H. The Manor House, Stoke Damerel, South Devon.
1883. ‡Alger, Mrs. W. H. The Manor House, Stoke Damerel, South Devon.
1867. ‡Alison, George L. C. Dundee.
1885. ‡Allan, David. West Cults, near Aberdeen.
1871. ‡Allan, G., M.Inst.C.E. 10 Austin Friars, E.C.
1901. *Allan, James A. Westerton, Milngavie.
1871. ‡ALLEN, ALFRED H., F.C.S. 67 Surrey-street, Sheffield.
1879. *Allen, Rev. A. J. C. The Librarian, Peterhouse, Cambridge.
1898. §ALLEN, E. J. The Laboratory, Citadel Hill, Plymouth.
1888. ‡ALLEN, F. J., M.A., M.D., Professor of Physiology, The University, Birmingham.
1884. ‡Allen, Rev. George. Shaw Vicarage, Oldham.
1891. ‡Allen, Henry A., F.G.S. Geological Museum, Jermyn-street, S.W.
1887. ‡Allen, John. 15 North Crescent, St. Anne's-on-the-Sea, viâ Preston.
1878. ‡Allen, John Romilly. 28 Great Ormond-street, W.C.
1889. ‡Allhusen, Alfred. Low Fell, Gateshead.
1889. ‡Allhusen, Frank E.
1886. ‡Allport, Samuel, F.G.S. The University, Birmingham.
1896. ‡Alsop, J. W. 16 Bidston-road, Oxton.
1882. *Alverstone, The Right Hon. Lord, G.C.M.G., LL.D. Hornton Lodge, Hornton Street, Kensington, S.W.
1887. ‡Alward, G. L. 11 Hamilton-street, Grimsby, Yorkshire.
1873. ‡Ambler, John. North Park-road, Bradford, Yorkshire.
1891. ‡Ambrose, D. R. Care of Messrs. J. Evans & Co., Bute Docks, Cardiff.
1883. §Amery, John Sparke. Druid, Ashburton, Devon.
1883. §Amery, Peter Fabyan Sparke. Druid, Ashburton, Devon.
1884. ‡AMI, HENRY, M.A., F.G.S. Geological Survey, Ottawa, Canada.
1883. ‡Anderson, Miss Constance. 17 Stonegate, York.
1885. *ANDERSON, HUGH KERR. Caius College, Cambridge.
1901. *Anderson, James. 1 Marlborough Terrace, Glasgow.
1874. ‡Anderson, John, J.P., F.G.S. Holywood, Belfast.
1892. ‡Anderson, Joseph, LL.D. 8 Great King-street, Edinburgh.
1899. *Anderson, Miss Mary K. 13 Napier-road, Edinburgh.
1888. *Anderson, R. Bruce. 35A Great George-street, S.W.
1887. ‡Anderson, Professor R. J., M.D., F.L.S. Queen's College, and Atlantic Lodge, Salthill, Galway.
1889. ‡Anderson, R. Simpson. Elswick Collieries, Newcastle-upon-Tyne.
1880. *ANDERSON, TEMPEST, M.D., B.Sc., F.G.S. (*Local Sec.* 1881). 17 Stonegate, York.
1901. *Anderson, Dr. W. Carrick. 2 Florentine Gardens, Glasgow.
1901. §Anderson, W. F. G. 47 Union Street, Glasgow.
1883. ‡Andrew, Thomas, F.G.S. 18 Southernhay, Exeter.
1895. ‡Andrews, Charles W. British Museum (Natural History), S.W.
1891. ‡Andrews, Thomas. 163 Newport-road, Cardiff.
1880. *Andrews, Thornton, M.Inst.C.E. Cefn Eithen, Swansea.
1886. §Andrews, William, F.G.S. Steeple Croft, Coventry.
1883. ‡Anelay, Miss M. Mabel. Girton College, Cambridge.
1877. §ANGELL, JOHN, F.C.S., F.I.C. 6 Beacons-field, Derby-road, Withington, Manchester.
1886. ‡Annan, John, J.P. Whitmore Reans, Wolverhampton.
1900. ‡Annandale, Nelson. 34 Charlotte Square, Edinburgh.
1896. ‡Annett, R. C. F. 11 Greenhey-road, Liverpool.
1886. ‡Ansell, Joseph. 38 Waterloo-street, Birmingham.

Year of Election.

1878. ‡Anson, Frederick H. 15 Dean's-yard, Westminster, S.W.
1890. §Antrobus, J. Coutts. Eaton Hall, Congleton.
1901. §Arakawa, Minozi. Japanese Consulate, 84 Bishopsgate Street Within, E.C.
1900. §Arber, E. A. N., B.A. Trinity College, Cambridge.
1898. ‡Archer, G. W. 11 All Saints'-road, Clifton, Bristol.
1894. §Archibald, A. The Bank House, Ventnor.
1884. *Archibald, E. Douglas. Constitutional Club, Northumberland Avenue, W.C.
1883. §Armistead, Richard. Chambres House, Southport.
1883. *Armistead, William. Hillcrest, Oaken, Wolverhampton.
1873. *Armstrong, Henry E., Ph.D., LL.D., F.R.S. (Pres. B, 1885; Council 1899–), Professor of Chemistry in the City and Guilds of London Institute, Central Institution, Exhibition-road, S.W. 55 Granville Park, Lewisham, S.E.
1876. ‡Armstrong, James. Bay Ridge, Long Island, New York, U.S.A.
1889. ‡Armstrong, Thomas John. 14 Hawthorn-terrace, Newcastle-upon-Tyne.
1893. ‡Arnold-Bemrose, H., M.A., F.G.S. 56 Friar-gate, Derby.
1901. §Arthur, Matthew. 78 Queen Street, Glasgow.
1870. *Ash, Dr. T. Linnington. Penroses, Holsworthy, North Devon.
1874. ‡Ashe, Isaac, M.B. Dundrum, Co. Dublin.
1889. ‡Ashley, Howard M. Airedale, Ferrybridge, Yorkshire.
1887. ‡Ashton, Thomas Gair, M.A. 36 Charlotte-street, Manchester.
*Ashworth, Edmund. Egerton Hall, Bolton-le-Moors.
Ashworth, Henry. Turton, near Bolton.
1888. *Ashworth, J. Jackson. Haslen House, Handforth, Cheshire.
1890. ‡Ashworth, J. Reginald, B.Sc. 105 Freehold-street, Rochdale.
1887. ‡Ashworth, John Wallwork, F.G.S. Thorne Bank, Heaton Moor, Stockport.
1887. ‡Ashworth, Mrs. J. W. Thorne Bank, Heaton Moor, Stockport.
1875. *Aspland, W. Gaskell. Tuplins, Newton Abbot.
1861. ‡Asquith, J. R. Infirmary-street, Leeds.
1896. *Assheton, Richard. Grantchester, Cambridge.
1861. ‡*Aston, Theodore. 11 New-square, Lincoln's Inn, W.C.*
1896. §Atkin, George, J.P. Egerton Park, Birkenhead.
1887. §Atkinson, Rev. C. Chetwynd, D.D. Ingestre, Ashton-on-Mersey.
1884. ‡Atkinson, Edward, Ph.D., LL.D. Brookline, Massachusetts, U.S.A.
1898. *Atkinson, E. Cuthbert. St. John's College, Oxford.
1894. ‡Atkinson, George M. 28 St. Oswald's-road, S.W.
1894. *Atkinson, Harold W. Rossall School, Fleetwood, Lancashire.
1881. ‡Atkinson, J. T. The Quay, Selby, Yorkshire.
1881. ‡Atkinson, Robert William, F.C.S. (Local Sec. 1891). 44 Loudoun-square, Cardiff.
1894. §Atkinson, William. Erwood, Beckenham, Kent.
1863. *Attfield, J., M.A., Ph.D., F.R.S., F.C.S. 111 Temple-chambers, E.C.
1884. ‡Auchincloss, W. S. 209 Church-street, Philadelphia, U.S.A.
1853. *Avebury, The Right Hon. Lord, D.C.L., F.R.S. (President, 1881; Trustee, 1872– ; Pres. D, 1872; Council 1865–71). High Elms, Farnborough, Kent.
1901. §Aveling, T. C. 32 Bristol Street, Birmingham.
1877. *Ayrton, W. E., F.R.S. (Pres. A, 1898; Council 1889–96), Professor of Electrical Engineering in the City and Guilds of London Institute, Central Institution, Exhibition-road, S.W. 41 Kensington Park-gardens, W.

Year of Election.

1884. ‡Baby, The Hon. G. Montreal, Canada.
1900. §BACCHUS, RAMSDEN (Local Sec. 1900). 15 Welbury Drive, Bradford.
1883. *Bach, Madame Henri. 12 Rue Fénélon, Lyons.
Backhouse, Edmund. Darlington.
1863. ‡Backhouse, T. W. West Hendon House, Sunderland.
1883. *Backhouse, W. A. St. John's, Wolsingham, R.S.O., Durham.
1887. *Bacon, Thomas Walter. Ramsden Hall, Billericay, Essex.
1887. ‡Baddeley, John. 1 Charlotte-street, Manchester.
1883. ‡Baildon, Dr. 65 Manchester-road, Southport.
1892. ‡Baildon, H. Bellyse. Duncliffe, Murrayfield, Edinburgh.
1883. *Bailey, Charles, F.L.S. Atherstone House, North Drive, St. Annes on the Sea, Lancashire.
1893. §BAILEY, Colonel F., Sec. R.Scot.G.S., F.R.G.S. 7 Drummond-place, Edinburgh.
1870. ‡Bailey, Dr. Francis J. 51 Grove-street, Liverpool.
1887. *Bailey, G. H., D.Sc., Ph.D. Marple Cottage, Marple, Cheshire.
1865. ‡Bailey, Samuel. Ashley House, Calthorpe-road, Edgbaston, Birmingham.
1890. ‡Bailey, T. Lewis. 35 Hawarden-avenue, Liverpool.
1855. ‡Bailey, W. Horseley Fields Chemical Works, Wolverhampton.
1894. *Baily, Francis Gibson, M.A. 11 Ramsay-garden, Edinburgh.
1878. ‡BAILY, WALTER. 4 Roslyn-hill, Hampstead, N.W.
1885. ‡BAIN, ALEXANDER, M.A., LL.D. Ferryhill Lodge, Aberdeen.
1897. §BAIN, JAMES, jun. Toronto.
1885. ‡Bain, William N. Collingwood, Pollokshields, Glasgow.
1882. *BAKER, Sir BENJAMIN, K.C.M.G., LL.D., D.Sc., F.R.S., M.Inst.C.E. (Pres. G, 1885; Council, 1889–96). 2 Queen Square-place, Westminster, S.W.
1886. §Baker, Harry, F.I.C. Epworth House, Moughland Lane, Runcorn.
1898. ‡Baker, Herbert M. Wallcroft, Durdham Park, Clifton, Bristol.
1898. ‡Baker, Hiatt C. Mary-le-Port-street, Bristol.
1891. ‡Baker, J. W. 50 Stacey-road, Cardiff.
1881. ‡Baker, Robert, M.D. The Retreat, York.
1875. ‡BAKER, W. PROCTOR. Bristol.
1881. ‡Baldwin, Rev. G. W. de Courcy, M.A. Warshill Vicarage, York.
1884. ‡Balete, Professor E. Polytechnic School, Montreal, Canada.
1871. ‡Balfour, The Right Hon. G. W., M.P. 24 Addison-road, Kensington, W.
1894. §Balfour, Henry, M.A. 11 Norham-gardens, Oxford.
1875. ‡BALFOUR, ISAAC BAYLEY, M.A., D.Sc., M.D., F.R.S., F.R.S.E., F.L.S., (Pres. D, 1894; K, 1901), Professor of Botany in the University of Edinburgh. Inverleith House, Edinburgh.
1883. ‡Balfour, Mrs. I. Bayley. Inverleith House, Edinburgh.
1878. *Ball, Charles Bent, M.D., Regius Professor of Surgery in the University of Dublin. 24 Merrion-square, Dublin.
1866. *BALL, Sir ROBERT STAWELL, LL.D., F.R.S., F.R.A.S. (Pres. A, 1887; Council 1884–90, 1892–94; Local Sec. 1878), Lowndean Professor of Astronomy and Geometry in the University of Cambridge. The Observatory, Cambridge.
1883. *Ball, W. W. Rouse, M.A. Trinity College, Cambridge.
1886. ‡Ballantyne, J. W., M.B. 24 Melville-street, Edinburgh.
1869. ‡Bamber, Henry K., F.C.S. 5 Westminster-chambers, Victoria-street, Westminster, S.W.
1890. ‡Bamford, Professor Harry, B.Sc. 3 Albany Street, Glasgow.
1899. §Bampton, Mrs. 42 Marine-parade, Dover.
1882. ‡Bance, Colonel Edward, J.P. Oak Mount, Highfield, Southampton.

Year of Election.

1898. ‡Bannerman, W. Bruce, F.R.G.S., F.G.S. The Lindens, Sydenham-road, Croydon.
1884. ‡Barbeau, E. J. Montreal, Canada.
1866. ‡Barber, John. Long-row, Nottingham.
1884. ‡Barber, Rev. S. F. West Raynham Rectory, Swaffham, Norfolk.
1890. *Barber-Starkey, W. J. S. Aldenham Park, Bridgnorth, Salop.
1861. *Barbour, George. Bolesworth Castle, Tattenhall, Chester.
1894. ‡Barclay, Arthur. 29 Gloucester-road, South Kensington, S.W.
1871. ‡Barclay, George. 17 Coates-crescent, Edinburgh.
1860. *Barclay, Robert. High Leigh, Hoddesden, Herts.
1887. *Barclay, Robert. Sedgley New Hall, Prestwich, Manchester.
1886. ‡Barclay, Thomas. 17 Bull-street, Birmingham.
1881. ‡Barfoot, William, J.P. Whelford-place, Leicester.
1882. ‡Barford, J. D. Above Bar, Southampton.
1886. ‡Barham, F. F. Bank of England, Birmingham.
1890. ‡Barker, Alfred, M.A., B.Sc. Aske's Hatcham School, New Cross, S.E.
1899. §Barker, John H. 68 Jesmond Road, Newcastle-on-Tyne.
1882. *Barker, Miss J. M. Hexham House, Hexham.
1879. *Barker, Rev. Philip C., M.A., LL.B. Priddy Vicarage, Wells, Somerset.
1898. §Barker, W. R. 106 Redland-road, Bristol.
1886. ‡Barling, Gilbert. 85 Edmund-street, Edgbaston, Birmingham.
1873. ‡Barlow, Crawford, B.A., M.Inst.C.E. Deene, Tooting Bec-road, Streatham, S.W.
1889. §Barlow, H. W. L., M.A., M.B., F.C.S. Holly Bank, Croftsbank-road, Urmston, near Manchester.
1883. ‡Barlow, J. J. 37 Park-street, Southport.
1878. ‡Barlow, John, M.D., Professor of Physiology in St. Mungo's College, Glasgow.
1883. ‡Barlow, John R. Greenthorne, near Bolton.
1885. *Barlow, William, F.G.S. The Red House, Great Stanmore.
1873. ‡Barlow, William Henry, F.R.S., M.Inst.C.E. (Pres. G, 1873; Council 1886–89). High Combe, Old Charlton, Kent.
1861. *Barnard, Major R. Cary, F.L.S. Bartlow, Leckhampton, Cheltenham.
1881. ‡Barnard, William, LL.B. 3 New-court, Lincoln's Inn, W.C.
1889. ‡Barnes, J. W. Bank, Durham.
1868. §Barnes, Richard H. Heatherlands, Parkstone, Dorset.
1899. ‡Barnes, Robert. 9 Kildare Gardens, Bayswater, W.
1884. ‡Barnett, J. D. Port Hope, Ontario, Canada.
1901. §Barnett, P. A. Board of Education, Whitehall, S.W.
1899. ‡Barnett, W. D. 41 Threadneedle-street, E.C.
1881. ‡Barr, Archibald, D.Sc., M.Inst.C.E. The University, Glasgow.
1890. ‡Barr, Frederick H. 4 South-parade, Leeds.
1859. ‡Barr, Lieut.-General. Apsleytoun, East Grinstead, Sussex.
1891. ‡Barrell, Frank R., M.A., Professor of Mathematics in University College, Bristol.
1883. ‡Barrett, John Chalk. Errismore, Birkdale, Southport.
1883. ‡Barrett, Mrs. J. C. Errismore, Birkdale, Southport.
1872. *Barrett, W. F., F.R.S., F.R.S.E., M.R.I.A., Professor of Physics in the Royal College of Science, Dublin.
1883. ‡Barrett, William Scott. Abbotsgate, Huyton, near Liverpool.
1890. ‡Barrett-Hamilton, Capt. G. E. H. Kilmarnock, Arthurstown, Waterford, Ireland.
1887. ‡Barrington, Miss Amy. Fassaroe, Bray, Co. Wicklow.
1874. *Barrington, R. M., M.A., LL.B., F.L.S. Fassaroe, Bray, Co. Wicklow.

Year of Election.

1874. *Barrington-Ward, Mark J., M.A., F.L.S., F.R.G.S., H.M. Inspector of Schools. Thorneloe Lodge, Worcester.
1885. *Barron, Frederick Cadogan, M.Inst.C.E. Nervion, Beckenham-grove, Shortlands, Kent.
1866. ‡Barron, William. Elvaston Nurseries, Borrowash, Derby.
1893. *BARROW, GEORGE, F.G.S. Geological Survey Office, 28 Jermyn-street, S.W.
1886. ‡Barrow, George William. Baldraud, Lancaster.
1886. ‡Barrow, Richard Bradbury. Lawn House, 13 Ampton-road, Edgbaston, Birmingham.
1896. §Barrowman, James. Staneacre, Hamilton, N.B.
1886. ‡Barrows, Joseph. The Poplars, Yardley, near Birmingham.
1886. ‡Barrows, Joseph, jun. Ferndale, Harborne-road, Edgbaston, Birmingham.
1858. ‡BARRY, Right Rev. ALFRED, D.D., D.C.L. The Cloisters, Windsor.
1883. ‡Barry, Charles E. 1 Victoria-street, S.W.
1881. ‡Barry, J. W. Duncombe-place, York.
1884. *Barstow, Miss Frances A. Garrow Hill, near York.
1890. *Barstow, J. J. Jackson. The Lodge, Weston-super-Mare.
1890. *Barstow, Mrs. The Lodge, Weston-super-Mare.
1892. ‡Bartholomew, John George, F.R.S.E., F.R.G.S. 12 Blacket-place, Edinburgh.
1858. *Bartholomew, William Hamond, M.Inst.C.E. Ridgeway House, Cumberland-road, Hyde Park, Leeds.
1884. ‡Bartlett, James Herbert. 148 Mansfield-street, Montreal, Canada.
1873. ‡Bartley, G. C. T., M.P. St. Margaret's House, Victoria-street, S.W.
1892. ‡Barton, Miss. 4 Glenorchy-terrace, Mayfield, Edinburgh.
1893. ‡Barton, Edwin H., B.Sc. University College, Nottingham.
1884. ‡Barton, H. M. Foster-place, Dublin.
1852. ‡Barton, James. Farndreg, Dundalk.
1899. *Barton, Miss Ethel S. 7 Brechin Place, South Kensington, S.W.
1892. ‡Barton, William. 4 Glenorchy-terrace, Mayfield, Edinburgh.
1887. ‡Bartrum, John S. 13 Gay-street, Bath.
*Bashforth, Rev. Francis, B.D. Minting Vicarage, near Horncastle.
1898. ‡Bason, Vernon Millward. 7 Princess-buildings, Clifton, Bristol.
1876. ‡Bassano, Alexander. 12 Montagu-place, W.
1888. *BASSET, A. B., M.A., F.R.S. Fledborough Hall, Holyport, Berkshire.
1891. ‡Bassett, A. B. Cheverell, Llandaff.
1866. *BASSETT, HENRY. 26 Belitha-villas, Barnsbury, N.
1880. ‡BASTABLE, Professor C. F., M.A., F.S.S. (Pres. F, 1894). 6 Trevelyan-terrace, Rathgar, Co. Dublin.
1869. ‡Bastard, S. S. Summerland-place, Exeter.
1871. ‡BASTIAN, H. CHARLTON, M.A., M.D., F.R.S., F.L.S., Emeritus Professor of the Principles and Practice of Medicine in University College, London. 8A Manchester-square, W.
1889. ‡Batalha-Reis, J. Portuguese Consulate, Newcastle-upon-Tyne.
1883. ‡BATEMAN, Sir A. E., K.C.M.G., Controller General, Statistical Department. Board of Trade, 7 Whitehall Gardens, S.W.
1868. ‡Bateman, Sir F., M.D., LL.D. Upper St. Giles's-street, Norwich.
1889. ‡Bates, C. J. Heddon, Wylam, Northumberland.
1884. ‡BATESON, WILLIAM, M.A., F.R.S. St. John's College, Cambridge.
1881. *BATHER, FRANCIS ARTHUR, M.A., D.Sc., F.G.S. British Museum (Natural History), S.W.
1863. §BAUERMAN, H., F.G.S. 14 Cavendish-road, Balham, S.W.
1867. ‡Baxter, Edward. Hazel Hall, Dundee.
1892. ‡Bayly, F. W. 8 Royal Mint, E.
1875. *Bayly, Robert. Torr Grove, near Plymouth.

Year of
Election.

1876. *BAYNES, ROBERT E., M.A. Christ Church, Oxford.
1887. *Baynes, Mrs. R. E. 2 Norham-gardens, Oxford.
1883. *Bazley, Gardner S. Hatherop Castle, Fairford, Gloucestershire.
Bazley, Sir Thomas Sebastian, Bart., M.A. Winterdyne, Chine Crescent-road, Bournemouth.
1886. ‡Beale, C. Calle Progress No. 83, Rosario de Santa Fé, Argentine Republic.
1886. ‡Beale, Charles G. Maple Bank, Edgbaston, Birmingham.
1860. *BEALE, LIONEL S., M.B., F.R.S. 61 Grosvenor-street, W.
1882. §Beamish, Lieut.-Colonel A. W., R.E. 27 Philbeach-gardens, S.W.
1884. ‡Beamish, G. H. M. Prison, Liverpool.
1872. ‡Beanes, Edward, F.C.S. Moatlands, Paddock Wood, Brenchley, Kent.
1883. ‡Beard, Mrs. Oxford.
1889. §BEARE, Prof. T. HUDSON, B.Sc., F.R.S.E., M.Inst.C.E. The University, Edinburgh.
1842. *Beatson, William. 2 Ash Mount, Rotherham.
1889. ‡Beattie, John. 5 Summerhill-grove, Newcastle-upon-Tyne.
1855. *Beaufort, W. Morris, F.R.A.S., F.R.G.S., F.R.M.S., F.S.S. 18 Piccadilly, W.
1886. ‡Beaugrand, M. H. Montreal.
1900. ‡Beaumont, Prof. Roberts, M.I.Mech.E. Yorkshire College, Leeds.
1861. *Beaumont, Rev. Thomas George. Oakley Lodge, Leamington.
1887. *Beaumont, W. J. The Laboratory, Citadel Hill, Plymouth.
1885. *BEAUMONT, W. W., M.Inst.C.E., F.G.S. Outer Temple, 222 Strand, W.C.
1896. ‡Beazer, C. Hindley, near Wigan.
1887. *BECKETT, JOHN HAMPDEN. Corbar Hall, Buxton, Derbyshire.
1885. ‡BEDDARD, FRANK E., M.A., F.R.S., F.Z.S., Prosector to the Zoological Society of London, Regent's Park, N.W.
1870. §BEDDOE, JOHN, M.D., F.R.S. (Council, 1870–75). The Chantry, Bradford-on-Avon.
1858. §Bedford, James. Woodhouse Cliff, near Leeds.
1890. ‡Bedford, James E., F.G.S. Shireoak-road, Leeds.
1891. §Bedlington, Richard. Gadlys House, Aberdare.
1878. ‡BEDSON, P. PHILLIPS, D.Sc., F.C.S. (Local Sec. 1889), Professor of Chemistry in the College of Physical Science, Newcastle-upon-Tyne.
1884. ‡Beers, W. G., M.D. 34 Beaver Hall-terrace, Montreal, Canada.
1873. ‡Behrens, Jacob. Springfield House, North-parade, Bradford, Yorkshire.
1901. *Beilby, George T. St. Kitts, Slateford, Midlothian.
1874. ‡Belcher, Richard Boswell. Blockley, Worcestershire.
1891. ‡Belinfante, L. L., M.Sc., Assist.-Sec. G.S. Burlington House, W.
1892. ‡Bell, A. Beatson. 17 Lansdowne Crescent, Edinburgh.
1871. ‡Bell, Charles B. 6 Spring-bank, Hull.
1884. ‡Bell, Charles Napier. Winnipeg, Canada.
1894. ‡BELL, F. JEFFREY, M.A., F.Z.S. 35 Cambridge-street, Hyde Park, W.
Bell, Frederick John. Woodlands, near Maldon, Essex.
1860. ‡BELL, Rev. GEORGE CHARLES, M.A. Marlborough College, Wilts.
1900. *Bell, H. Wilkinson. Holmehurst, Rawdon, near Leeds.
1862. *BELL, Sir ISAAC LOWTHIAN, Bart., LL.D., F.R.S., F.C.S., M.Inst.C.E. (Pres. B, 1889). Rounton Grange, Northallerton.
1875. ‡BELL, JAMES, C.B., D.Sc., Ph.D., F.R.S. 52 Cromwell-road, Hove, Brighton.
1896. ‡Bell, James. Care of the Liverpool Steam Tug Co., Limited, Chapel-chambers, 28 Chapel-street, Liverpool.

Year of Election.

1891. ‡*Bell, James. Bangor Villa, Clive-road, Cardiff.*
1871. *Bell, J. Carter, F.C.S. Bankfield, The Cliff, Higher Broughton, Manchester.
1883. *Bell, John Henry. 100 Leyland-road, Southport.
1864. ‡Bell, R. Queen's College, Kingston, Canada.
1888. *Bell, Walter George, M.A. Trinity Hall, Cambridge.
1893. ‡Belper, The Right Hon. Lord, LL.M. Kingston, Nottinghamshire.
1884. ‡Bemrose, Joseph. 15 Plateau-street, Montreal, Canada.
1886. §Benger, Frederick Baden, F.I.C., F.C.S. The Grange, Knutsford.
1885. ‡Benham, William Blaxland, D.Sc., Professor of Biology in the University of Otago, New Zealand.
1891. ‡Bennett, Alfred Rosling. 44 Manor Park-road, Harlesden, N.W.
1896. ‡Bennett, George W. West Ridge, Oxton, Cheshire.
1881. ‡Bennett, John Ryan. 3 Upper Belgrave-road, Clifton, Bristol.
1883. *Bennett, Laurence Henry. The Elms, Paignton, South Devon.
1901. §Bennett, Peter. 6 Kelvinhaugh Street, Kelvinside, Glasgow.
1896. ‡Bennett, Richard. 19 Brunswick-street, Liverpool.
1881. ‡Bennett, Rev. S. H., M.A. St. Mary's Vicarage, Bishopshill Junior, York.
1889. ‡Benson, John G. 12 Grey-street, Newcastle-upon-Tyne.
1901. *Benson, Miss Margaret, D.Sc. Royal Holloway College, Egham.
1887. *Benson, Mrs. W. J. Care of Standard Bank of South Africa, Stellenbosch, South Africa.
1863. ‡Benson, William. Fourstones Court, Newcastle-upon-Tyne.
1898. *Bent, Mrs. Theodore. 13 Great Cumberland-place, W.
1884. ‡Bentham, William. 724 Sherbrooke-street, Montreal, Canada.
1897. ‡Bently, R. R. 97 Dowling-avenue, Toronto, Canada.
1896. *Bergin, William, M.A., Professor of Natural Philosophy in Queen's College, Cork.
1901. §Bergins, Walter L. 8 Marlborough Terrace, Glasgow.
1894. §Berkeley, The Right Hon. the Earl of. Foxcombe, Boarshill, near Abingdon.
1863. ‡Berkley, C. Marley Hill, Gateshead, Durham.
1886. ‡Bernard, W. Leigh. Calgary, Canada.
1898. §Berridge, Miss C. E. Wellscot, Hayward's Lane, Cheltenham.
1894. §Berridge, Douglas, M.A., F.C.S. The College, Malvern.
1862. ‡Besant, William Henry, M.A., D.Sc., F.R.S. St. John's College, Cambridge.
1882. *Bessemer, Henry. Moorlands, Bitterne, Southampton.
1890. ‡Best, William Woodham. 31 Lyddon-terrace, Leeds.
1880. *Bevan, Rev. James Oliver, M.A., F.S.A., F.G.S. 55 Gunterstone-road, W.
1885. ‡Beveridge, R. Beath Villa, Ferryhill, Aberdeen.
1884. *Beverley, Michael, M.D. 54 Prince of Wales-road, Norwich.
1870. ‡Bickerton, A. W. Newland Terrace, Queen's Road, Battersea, S.W.
1888. *Bidder, George Parker. Savile Club, Piccadilly, W.
1885. *Bidwell, Shelford, Sc.D., LL.B., F.R.S. Riverstone Lodge, Southfields, Wandsworth, Surrey, S.W.
1882. §Biggs, C. H. W., F.C.S. Glebe Lodge, Champion Hill, S.E.
1898. §Billington, Charles. Studleigh, Longport, Staffordshire.
1901. *Bilsland, William, J.P. 28 Park Circus, Glasgow.
1886. ‡Bindloss, G. F. Carnforth, Brondesbury Park, N.W.
1887. *Bindloss, James B. Elm Bank, Eccles, Manchester.
1884. *Bingham, Lieut.-Colonel John E., J.P. West Lea, Ranmoor, Sheffield.
1881. ‡Binnie, Sir Alexander R., M.Inst.C.E., F.G.S. (Pres. G, 1900). 77 Ladbroke Grove, W.

Year of Election.

1873. ‡Binns, J. Arthur. 31 Manor Row, Manningham, Bradford, Yorkshire.
1900. †Bird, F. J. Norton House, Midsomer Norton, Bath.
1880. ‡Bird, Henry, F.C.S. South Down House, Millbrook, near Devonport.
1888. *Birley, Miss Caroline. 14 Brunswick-gardens, Kensington, W.
1887. *Birley, H. K. Hospital, Chorley, Lancashire.
1871. *Bischof, Gustav. 19 Ladbroke-gardens, W.
1894. ‡Bisset, James. 5 East India-avenue, E.C.
1885. ‡Bissett, J. P. Wyndem, Banchory, N.B.
1886. *Bixby, Major W. H. Engineer's Office, Jones Building, Detroit, Michigan, U.S.A.
1901. §Black, John Albert. Lagarie Row, Helensburgh, N.B.
1889. ‡Black, W. 1 Lovaine-place, Newcastle-upon-Tyne.
1881. ‡Black, Surgeon-Major William Galt, F.R.C.S.E. Caledonian United Service Club, Edinburgh.
1901. §Black, W. P. M. 15 Montgomerie Street, Kelvinside, Glasgow.
1876. ‡Blackburn, Hugh, M.A. Roshven, Fort William, N.B.
1884. ‡Blackburn, Robert. New Edinburgh, Ontario, Canada.
1900. §Blackburn, W. Owen. 3 Mount Royd, Bradford.
1877. ‡Blackie, J. Alexander. 17 Stanhope-street, Glasgow.
1855. *Blackie, W. G., Ph.D., F.R.G.S. (Local Sec. 1876). 1 Belhaven-terrace, Kelvinside, Glasgow.
1896. §Blackie, Walter W., B.Sc. 17 Stanhope-street, Glasgow.
1884. ‡Blacklock, Frederick W. 25 St. Famille-street, Montreal, Canada.
1896. ‡Blackwood, J. M. 16 Oil-street, Liverpool.
1886. ‡Blaikie, John, F.L.S. The Bridge House, Newcastle, Staffordshire.
1895. ‡Blaikie, W. B. 6 Belgrave-crescent, Edinburgh.
1883. ‡Blair, Mrs. Oakshaw, Paisley.
1892. ‡Blair, Alexander. 35 Moray-place, Edinburgh.
1892. ‡Blair, John. 9 Ettrick-road, Edinburgh.
1883. *Blake, Rev. J. F., M.A., F.G.S. 69 Comeragh-road, W.
1891. ‡Blakesley, Thomas H., M.A., M.Inst.C.E. Royal Naval College, Greenwich, S.E.
1894. ‡Blakiston, Rev. C. D. Exwick Vicarage, Exeter.
1900. *Blamires, Joseph. Bradley Lodge, Huddersfield.
1881. ‡Blamires, Thomas H. Close Hill, Lockwood, near Huddersfield.
1895. ‡Blamires, William. Oak House, Taylor Hill, Huddersfield.
1884. *Blandy, William Charles, M.A. 1 Friar-street, Reading.
1869. ‡Blanford, W. T., LL.D., F.R.S., F.G.S., F.R.G.S. (Pres. C, 1884; Council 1885-91). 72 Bedford-gardens, Campden Hill, W.
1887. *Bles, A. J. S. Palm House, Park-lane, Higher Broughton, Manchester.
1887. *Bles, Edward J., B.Sc. Newnham Lea, Grange-road, Cambridge.
1887. ‡Bles, Marcus S. The Beeches, Broughton Park, Manchester.
1884. *Blish, William G. Niles, Michigan, U.S.A.
1888. §Bloxsom, Martin, B.A., Assoc.M.Inst.C.E. Hazelwood, Crumpsall Green, Manchester.
1870. ‡Blundell, Thomas Weld. Ince Blundell Hall, Great Crosby.
Blyth, B. Hall. 135 George-street, Edinburgh.
1885. ‡Blyth, James, M.A., F.R.S.E., Professor of Natural Philosophy in Anderson's College, Glasgow.
1867. *Blyth-Martin, W. Y. Blyth House, Newport, Fife.
1887. ‡Blythe, William S. 65 Mosley-street, Manchester.
1901. §Blythswood, The Right Hon. Lord, LL.D. Blythswood, Renfrew.
1870. ‡Boardman, Edward. Oak House, Eaton, Norwich.

Year of Election.

1887. *Boddington, Henry. Pownall Hall, Wilmslow, Manchester.
1900. †Bodington, Principal N., M.A. Yorkshire College, Leeds.
1889. ‡Bodmer, G. R., Assoc.M.Inst.C.E. 30 Walbrook, E.C.
1884. ‡Body, Rev. C. W. E., M.A. Trinity College, Toronto, Canada.
1900. §Boileau, Major A. C. F., R.A. Royal Artillery Institution, Woolwich.
1887. *Boissevain, Gideon Maria. 4 Tesselschade-straat, Amsterdam.
1898. §Bolton, H. The Museum, Queen's-road, Bristol.
1894. §Bolton, John. 15 Clifton-road, Crouch End, N.
1898. ‡Bolton, J. W. Baldwin-street, Bristol.
1898. §Bonar, J., M.A., LL.D. (Pres. F, 1898; Council 1899–). 1 Redington-road, Hampstead, N.W.
1883. ‡Bonney, Frederic, F.R.G.S. Colton House, Rugeley, Staffordshire.
1871. *Bonney, Rev. Thomas George, D.Sc., LL.D., F.R.S., F.S.A., F.G.S. (Secretary, 1881–85; Pres. C, 1886). 23 Denning-road, Hampstead, N.W.
1888. ‡Boon, William. Coventry.
1893. ‡Boot, Jesse. Carlyle House, 18 Burns-street, Nottingham.
1890. *Booth, Charles, D.Sc., F.R.S., F.S.S. 24 Great Cumberland Place, W.
1883. ‡Booth, James. Hazelhurst, Turton.
1883. ‡Booth, Richard. 4 Stone-buildings, Lincoln's Inn, W.C.
1876. ‡Booth, Rev. William H. Mount Nod-road, Streatham, S.W.
1883. ‡Boothroyd, Benjamin. Solihull, Birmingham.
1901. *Boothroyd, Herbert E. Sidney Sussex College, Cambridge.
1900. §Borchgrevink, C. E. Douglas Lodge, Bromley, Kent.
1876. *Borland, William. 260 West George-street, Glasgow.
1882. §Borns, Henry, Ph.D., F.C.S. 19 Alexandra-road, Wimbledon, Surrey.
1901. §Borradaile, L. A. Selwyn College, Cambridge.
1876. *Bosanquet, R. H. M., M.A., F.R.S., F.R.A.S. Castillo Zamora, Realejo-Alto, Tenerife.
1896. ‡Bose, Dr. J. C. Calcutta, India.
*Bossey, Francis, M.D. Mayfield, Oxford-road, Redhill, Surrey.
1881. §Bothamley, Charles H., F.I.C., F.C.S., Director of Technical Instruction, Somerset County Education Committee. Hurst Knoll, Weston-super-Mare.
1887. ‡Bott, Dr. Owens College, Manchester.
1872. ‡Bottle, Alexander. 4 Godwyne-road, Dover.
1868. ‡Bottle, J. T. 28 Nelson-road, Great Yarmouth.
1887. †Bottomley, James, D.Sc., B.A. 220 Lower Broughton-road, Manchester.
1871. *Bottomley, James Thomson, M.A., D.Sc., F.R.S., F.R.S.E., F.C.S. 13 University-gardens, Glasgow.
1884. *Bottomley, Mrs. 13 University-gardens, Glasgow.
1892. ‡Bottomley, W. B., B.A., Professor of Botany, King's College, W.C.
1876. ‡Bottomley, William, jun. 15 University-gardens, Glasgow.
1890. †Boulnois, Henry Percy, M.Inst.C.E. 44 Campden House Court, Kensington, W.
1883. ‡Bourdas, Isaiah. Dunoon House, Clapham Common, S.W.
1883. †Bourne, A. G., D.Sc., F.R.S., F.L.S., Professor of Biology in the Presidency College, Madras.
1893. *Bourne, G. C., M.A., F.L.S. (Local Sec. 1894). Savile House, Mansfield-road, Oxford.
1866. ‡Bourne, Stephen. 5 Lansdown-road, Lee, S.E.
1890. ‡Bousfield, C. E. 55 Clarendon-road, Leeds.
1898. ‡Bovey, Edward P., jun. Clifton Grove, Torquay.

Year of Election.

1884. ‡BOVEY, HENRY T., M.A., M.Inst.C.E., Professor of Civil Engineering and Applied Mechanics in McGill University, Montreal. Ontario-avenue, Montreal, Canada.
1888. ‡Bowden, Rev. G. New Kingswood School, Lansdown, Bath.
1881. *BOWER, F. O., D.Sc., F.R.S., F.R.S.E., F.L.S. (Pres. K, 1898; Council 1900–), Regius Professor of Botany in the University of Glasgow.
1898. *Bowker, Arthur Frank, F.R.G.S., F.G.S. Royal Societies Club, St. James's-street, S.W.
1856. *Bowlby, Miss F. E. 23 Lansdowne-parade, Cheltenham.
1898. §BOWLEY, A. L., M.A. Waldeck House, Southern Hill, Reading.
1880. ‡Bowly, Christopher. Cirencester.
1887. ‡Bowly, Mrs. Christopher. Cirencester.
1865. ‡Bowman, F. H., D.Sc., F.R.S.E. Mayfield, Knutsford, Cheshire.
1899. *Bowman, Herbert Lister, M.A. 13 Sheffield-gardens, Kensington, W.
1899. *Bowman, John Herbert. 13 Sheffield Gardens, Kensington, W.
1887. §Box, Alfred Marshall. Care of Cooper, Box & Co., 69 Aldermanbury, E.C.
1895. *BOYCE, RUBERT, M.B., Professor of Pathology, University College, Liverpool.
1901. §Boyd, David T. Rhinsdale, Ballieston, Lanark.
1871. ‡Boyd, Thomas J. 41 Moray-place, Edinburgh.
1884. *Boyle, R. Vicars, C.S.I. Care of Messrs. Grindlay & Co., 55 Parliament-street, S.W.
1892. §BOYS, CHARLES VERNON, F.R.S. (Council, 1893–99). 27 The Grove, Boltons, S.W.
1872. *BRABROOK, E. W., C.B., F.S.A. (Pres. H, 1898). 178 Bedford-hill, Balham, S.W.
1869. *Braby, Frederick, F.G.S., F.C.S. Bushey Lodge, Teddington, Middlesex.
1894. *Braby, Ivon. Bushey Lodge, Teddington, Middlesex.
1893. §Bradley, F. L. Bel Air, Alderley Edge, Cheshire.
1899. *Bradley, J. W., Assoc.M.Inst.C.E. Town Hall, Wolverhampton.
1892. §Bradshaw, W. Carisbrooke House, The Park, Nottingham.
1863. ‡BRADY, GEORGE S., M.D., LL.D., F.R.S., Professor of Natural History in the Durham College of Science, Newcastle-on-Tyne. 2 Mowbray-villas, Sunderland.
1880. *Brady, Rev. Nicholas, M.A. Rainham Hall, Rainham, S.O., Essex.
1864. ‡*Braham, Philip. 3 Cobden-mansions, Stockwell-road, S.E.*
1888. §Braikenridge, W. J., J.P. 16 Royal-crescent, Bath.
1898. ‡Bramble, James R. Seafield, Weston-super-Mare.
1865. §BRAMWELL, Sir FREDERICK J., Bart., D.C.L., LL.D., F.R.S., M.Inst.C.E. (PRESIDENT, 1888; Pres. G, 1872, 1884; Council 1873–79, 1883–87). 5 Great George-street, S.W.
1867. ‡Brand, William. Milnefield, Dundee.
1861. *Brandreth, Rev. Henry. 72 Hills Road, Cambridge.
1885. *Bratby, William, J.P. Alton Lodge, Hale, Bowdon, Cheshire.
1890. *Bray, George. Belmont, Headingley, Leeds.
1868. ‡Bremridge, Elias. 17 Bloomsbury-square, W.C.
1877. ‡*Brent, Francis. 19 Clarendon-place, Plymouth.*
1898. §Brereton, Cuthbert A., M.Inst.C.E. 21 Delahay-street, S.W.
1882. *Bretherton, C. E. 26 Old Broad Street, E.C.
1866. ‡Brettell, Thomas. Dudley.
1891. ‡Brice, Arthur Montefiore, F.G.S., F.R.G.S. 28 Addison Mansions, Kensington, W.
1886. ‡BRIDGE, T. W., M.A., D.Sc., Professor of Zoology in the University, Birmingham.

Year of Election.
1870. *Bridson, Joseph R. Holybourne, Alton, Hants.
1887. ‡Brierley, John, J.P. The Clough, Whitefield, Manchester.
1870. ‡Brierley, Joseph. New Market-street, Blackburn.
1886. ‡Brierley, Leonard. Somerset-road, Edgbaston, Birmingham.
1879. ‡Brierley, Morgan. Denshaw House, Saddleworth.
1870. *Brigg, John, M.P. Kildwick Hall, Keighley, Yorkshire.
1890. ‡Brigg, W. A. Kildwick Hall, Keighley, Yorkshire.
1893. ‡Bright, Joseph. Western-terrace, The Park, Nottingham.
1868. ‡Brine, Admiral Lindesay, F.R.G.S. United Service Club, Pall Mall, S.W.
1893. ‡Briscoe, Albert E., B.Sc., A.R.C.Sc. Municipal Technical Institute, Romford-road, West Ham, E.
1884. ‡Brisette, M. H. 424 St. Paul-street, Montreal, Canada.
1898. ‡Bristol, the Right Rev. G. F. Browne, Lord Bishop of, D.D. 17 The Avenue, Clifton, Bristol.
1879. *Brittain, W. H., J.P., F.R.G.S. Storth Oaks, Sheffield.
1878. ‡Britten, James, F.L.S. Department of Botany, British Museum, S.W.
1884. *Brittle, John R., M.Inst.C.E., F.R.S.E. 9 Vanbrugh-hill, Blackheath, S.E.
1899. ‡Broadwood, Miss Bertha M. Pleystowe, Capel, Surrey.
1899. ‡Broadwood, James H. E. Pleystowe, Capel, Surrey.
1897. ‡Brock, W. R. Toronto.
1896. *Brocklehurst, S. Olinda, Sefton Park, Liverpool.
1883. *Brodie, David, M.D. 68 Hamilton Road, Highbury, N.
1901. §Brodie, T. G. Examination Hall, Victoria Embankment, W.C.
1884. †Brodie, William, M.D. 64 Lafayette-avenue, Detroit, Michigan, U.S.A.
1901. §Brodie, W. Brodie. 28 Hamilton Park Terrace, Hillhead, Glasgow.
1883. *Brodie-Hall, Miss W. L. 5 Devonshire-place, Eastbourne.
1881. ‡Brook, Robert G. Wolverhampton House, St. Helens, Lancashire.
1864. *Brooke, Ven. Archdeacon J. Ingham. The Vicarage, Halifax.
1887. §Brooks, James Howard. Elm Hirst, Wilmslow, near Manchester.
1863. ‡Brooks, John Crosse. 14 Lovaine-place, Newcastle-on-Tyne.
1887. ‡Brooks, S. H. Slade House, Levenshulme, Manchester.
1883. *Brotherton, E. A Arthington Hall, Wharfedale, viâ Leeds.
1901. §Brough, Bennett H., F.I.C., F.G.S. 28 Victoria Street, S.W., and Cranleigh House, near Addlestone, Surrey.
1883. *Brough, Mrs. Charles S. Rosendale Hall, West Dulwich, S.E.
1886. ‡Brough, Professor Joseph, LL.M., Professor of Logic and Philosophy in University College, Aberystwith.
1885. *Browett, Alfred. 29 Wheeley's-road, Birmingham.
1863. *Brown, Alexander Crum, M.D., LL.D., F.R.S., F.R.S.E., V.P.C.S. (Pres. B, 1874; Local Sec. 1871), Professor of Chemistry in the University of Edinburgh. 8 Belgrave-crescent, Edinburgh.
1892. ‡Brown, Andrew, M.Inst.C.E. Messrs. Wm. Simons & Co., Renfrew near Glasgow.
1896. ‡Brown, A. T. The Nunnery, St. Michael's Hamlet, Liverpool.
1867. ‡Brown, Sir Charles Gage, M.D., K.C.M.G. 88 Sloane-street, S.W.
1855. ‡Brown, Colin. 192 Hope-street, Glasgow.
1871. ‡Brown, David. Willowbrae House, Midlothian.
1863. *Brown, Rev. Dixon. Unthank Hall, Haltwhistle, Carlisle.
1883. †Brown, Mrs. Ellen F. Campbell. 27 Abercromby-square, Liverpool.
1881. ‡Brown, Frederick D. 26 St. Giles's-street, Oxford.
1883. ‡Brown, George Dransfield. Henley Villa, Ealing, Middlesex, W.

Year of Election.

1883. *Brown, Mrs. H. Bienz. Fochabers, Morayshire.
1883. ‡Brown, Mrs. Helen. Canaan-grove, Newbattle-terrace, Edinburgh.
1870. §BROWN, HORACE T., LL.D., F.R.S., F.G.S. (Pres. B, 1899). 52 Nevern-square, S.W.
Brown, Hugh. Broadstone, Ayrshire.
1883. ‡Brown, Miss Isabella Spring. Canaan-grove, Newbattle-terrace, Edinburgh.
1895. ‡BROWN, J. ALLEN, J.P., F.R.G.S., F.G.S. 7 Kent-gardens, Ealing, W.
1870. *BROWN, Professor J. CAMPBELL, D.Sc., F.C.S. University College, Liverpool.
1876. §BROWN, JOHN (LOCAL SECRETARY, 1902). Longhurst, Dunmurry, Belfast.
1881. *Brown, John, M.D. Stockbridge House, Padisham, Lancashire.
1882. *Brown, John. 7 Second-avenue, Nottingham.
1895. *Brown, John Charles. 2 Baker-street, Nottingham.
1894. ‡Brown, J. H. 6 Cambridge-road, Brighton.
1882. *Brown, Mrs. Mary. Stockbridge House, Padisham, Lancashire.
1898. §Brown, Nicol, F.G.S. 4 The Grove, Highgate, N.
1897. ‡Brown, Price, M.B. 37 Carlton-street, Toronto, Canada.
1886. §Brown, R., R.N. Laurel Bank, Barnhill, Perth.
1863. ‡Brown, Ralph. Lambton's Bank, Newcastle-upon-Tyne.
1897. ‡Brown, Richard. Jarvis-street, Toronto, Canada.
1901. §Brown, R. N. R., B.Sc. University College, Dundee.
1896. ‡Brown, Stewart H. Quarry Bank, Allerton, Liverpool.
1891. §BROWN, T. FORSTER, M.Inst.C.E., F.G.S. (Pres. G, 1891). Guild Hall Chambers, Cardiff.
1885. ‡Brown, W. A. The Court House, Aberdeen.
1884. ‡Brown, William George. Ivy, Albemarle Co., Virginia, U.S.A.
1863. ‡Browne, Sir Benjamin Chapman, M.Inst.C.E. Westacres, Newcastle-upon-Tyne.
1900. §Browne, Frank Balfour. Goldielea, Dumfries. Scotland.
1892. ‡*Browne, Harold Crichton. Crindon, Dumfries.*
1895. *Browne, H. T. Doughty. 10 Hyde Park-terrace, W.
1879. ‡BROWNE, Sir J. CRICHTON, M.D., LL.D., F.R.S., F.R.S.E. 61 Carlisle-place-mansions, Victoria-street, S.W.
1891. ‡BROWNE, MONTAGU, F.G.S. Town Museum, Leicester.
1862. *Browne, Robert Clayton, M.A. Browne's Hill, Carlow, Ireland.
1872. ‡Browne, R. Mackley, F.G.S. Redcot, Bradbourne, Sevenoaks, Kent.
1865. ‡Browning, John, F.R.A.S. 63 Strand, W.C.
1883. ‡Browning, Oscar, M.A. King's College, Cambridge.
1892. ‡Bruce, James. 10 Hill-street, Edinburgh.
1901. §Bruce, John. Inverallan, Helensburgh.
1893. ‡Bruce, William S. 11 Mount Pleasant, Joppa, Edinburgh.
1900. *Brumm, Charles. Lismara, Grosvenor Road, Birkdale, Southport.
1863. *Brunel, H. M., M.Inst.C.E. 21 Delahay-street, Westminster, S.W.
1863. ‡Brunel, I. 15 Devonshire-terrace, W.
1875. ‡Brunlees, John, M.Inst.C.E. 12 Victoria-street, Westminster, S.W.
1896. *Brunner, Sir J. T., Bart., M.P. Druid's Cross, Wavertree, Liverpool.
1868. ‡BRUNTON, Sir T. LAUDER, M.D., D.Sc., F.R.S. 10 Stratford-place, Oxford-street, W.
1897. *Brush, Charles F. Cleveland, Ohio, U.S.A.
1878. ‡Brutton, Joseph. Yeovil.
1886. *BRYAN, G. H., D.Sc., F.R.S., Professor of Mathematics in University College, Bangor.
1894. ‡Bryan, Mrs. R. P. Plas Gwyn, Bangor.
1884. ‡BRYCE, Rev. Professor GEORGE. Winnipeg, Canada.

Year of Election.

1897. ‡BRYCE, Right Hon. JAMES, D.C.L., M.P., F.R.S. 54 Portland-place, W.
1901. §Bryce, Thomas H. 2 Granby-terrace, Hillhead, Glasgow.
1894. ‡Brydone, R. M. Petworth, Sussex.
1890. §Bubb, Henry. Ullenwood, near Cheltenham.
1871. §BUCHAN, ALEXANDER, M.A., LL.D., F.R.S., F.R.S.E., Sec. Scottish Meteorological Society. 42 Heriot-row, Edinburgh.
1867. ‡Buchan, Thomas. Strawberry Bank, Dundee.
1901. §Buchanan, James, M.D. 12 Hamilton Drive, Maxwell Park, Glasgow.
1881. *Buchanan, John H., M.D. Sowerby, Thirsk.
1871. ‡BUCHANAN, JOHN YOUNG, M.A., F.R.S., F.R.S.E., F.R.G.S., F.C.S. Christ's College, Cambridge.
1884. ‡Buchanan, W. Frederick. Winnipeg, Canada.
1883. ‡Buckland, Miss A. W. 5 Beaumont-crescent, West Kensington, W.
1886. *Buckle, Edmund W. 23 Bedford-row, W.C.
1886. ‡Buckley, Samuel. Merlewood, Beaver Park, Didsbury.
1884. *Buckmaster, Charles Alexander, M.A., F.C.S. 16 Heathfield-road, Mill Hill Park, W.
1851. *BUCKTON, GEORGE BOWDLER, F.R.S., F.L.S., F.C.S. Weycombe, Haslemere, Surrey.
1887. ‡Budenberg, C. F., B.Sc. Buckau Villa, Demesne-road, Whalley Range, Manchester.
1901. §Budgett, J. S. Trinity College, Cambridge.
1875. ‡Budgett, Samuel. Penryn, Beckenham, Kent.
1883. ‡Buick, Rev. George R., M.A. Cullybackey, Co. Antrim, Ireland.
1893. §BULLEID, ARTHUR, F.S.A. Glastonbury.
1871. ‡Bulloch, Matthew. 48 Prince's-gate, S.W.
1883. ‡Bulpit, Rev. F. W. Crossens Rectory, Southport.
1895. ‡Bunte, Dr. Hans. Karlsruhe, Baden.
1886. §BURBURY, S. H., M.A., F.R.S. 1 New-square, Lincoln's Inn, W.C.
1842. *Burd, John. Glen Lodge, Knocknerea, Sligo.
1869. ‡Burdett-Coutts, Baroness. 1 Stratton-street, Piccadilly, W.
1881. ‡Burdett-Coutts, William Lehmann, M.P. 1 Stratton-street, Piccadilly, W.
1891. ‡Burge, Very Rev. T. A. Ampleforth Cottage, near York.
1894. ‡BURKE, JOHN B. B. Trinity College, Cambridge.
1884. *Burland, Lieut.-Col. Jeffrey H. 824 Sherbrook-street, Montreal, Canada.
1899. §Burls, Herbert T. Care of H. S. King & Co., Cornhill, E.C.
1888. ‡Burne, H. Holland. 28 Marlborough-buildings, Bath.
1883. *Burne, Major-General Sir Owen Tudor, G.C.I.E., K.C.S.I., F.R.G.S. 132 Sutherland-gardens, Maida Vale, W.
1876. ‡Burnet, John. 14 Victoria-crescent, Dowanhill, Glasgow.
1885. *Burnett, W. Kendall, M.A. Migvie House, Aberdeen.
1877. ‡Burns, David. Alston, Carlisle.
1884. ‡Burns, Professor James Austin. Southern Medical College, Atlanta, Georgia, U.S.A.
1899. ‡Burr, Malcolm. Dorman's Park, East Grinstead.
1887. ‡Burroughs, Eggleston, M.D. Snow Hill-buildings, E.C.
1860. ‡Burrows, Montague, M.A. Oxford.
1894. ‡Burstall, H. F. W. 76 King's-road, Camden-road, N.W.
1891. ‡Burt, J. J. 103 Roath-road, Cardiff.
1888. ‡Burt, John Mowlem. 3 St. John's-gardens, Kensington, W.
1888. ‡Burt, Mrs. 3 St. John's-gardens, Kensington, W.
1894. ‡Burton, Charles V. 24 Wimpole-street, W.
1866. *BURTON, FREDERICK M., F.L.S., F.G.S. Highfield, Gainsborough, Lincolnshire.
1889. ‡Burton, Rev. R. Lingen. Little Aston, Sutton Coldfield.

Year of Election.

1897. ‡Burton, S. H., M.B. 50 St. Giles's-street, Norwich.
1892. ‡Burton-Brown, Colonel Alexander, R.A., F.R.A.S., F.G.S. 11 Union Crescent, Margate.
1897. ‡Burwash, Rev. N., LL.D., Principal of Victoria University, Toronto, Canada.
1887. *Bury, Henry. Mayfield House, Farnham, Surrey.
1899. §Bush, Anthony. 43 Portland-road, Nottingham.
1895. §Bushe, Colonel C. K., F.G.S. 19 Cromwell-road, S.W.
1878. ‡BUTCHER, J. G., M.A. 22 Collingham-place, S.W.
1884. *Butcher, William Deane, M.R.C.S.Eng. Holyrood, 5 Cleveland-road, Ealing, W.
1884. ‡Butler, Matthew I. Napanee, Ontario, Canada.
1884. *Butterworth, W. Park Avenue, Temperley, near Manchester.
1872. ‡Buxton, Charles Louis. Cromer, Norfolk.
1887. *Buxton, J. H. Clumber Cottage, Montague-road, Felixstowe.
1881. ‡Buxton, Sydney. 15 Eaton-place, S.W.
1868. ‡Buxton, S. Gurney. Catton Hall, Norwich.
1872. ‡Buxton, Sir Thomas Fowell, Bart., G.C.M.G., F.R.G.S. Warlies, Waltham Abbey, Essex.
1854. ‡BYERLEY, ISAAC, F.L.S. 22 Dingle-lane, Toxteth Park, Liverpool.
1899. §Byles, Arthur R. 'Bradford Observer,' Bradford, Yorkshire.
1885. ‡Byres, David. 63 North Bradford, Aberdeen.
1852. ‡Byrne, Very Rev. James. Ergenagh Rectory, Omagh.
1883. ‡Byrom, John R. Mere Bank, Fairfield, near Manchester.

1889. ‡Cackett, James Thoburn. 60 Larkspur-terrace, Newcastle-upon-Tyne.
1892. ‡Cadell, Henry M., B.Sc., F.R.S.E. Grange, Bo'ness, N.B.
1894. ‡Caillard, Miss E. M. Wingfield House, near Trowbridge, Wilts.
1863. ‡Caird, Edward. Finnart, Dumbartonshire.
1861. *Caird, James Key. 8 Roseangle, Dundee.
1901. §Caldwell, Hugh. Blackwood, Newport, Mon.
1886. **Caldwell, William Hay. Cambridge.*
1868. ‡Caley, A. J. Norwich.
1887. ‡CALLAWAY, CHARLES, M.A., D.Sc., F.G.S. 35 Huskisson-street, Liverpool.
1897. §CALLENDAR, Prof. HUGH L., M.A., F.R.S. (Council, 1900–). 2 Chester Place, Regent's Park, N.W.
1892. ‡Calvert, A. F., F.R.G.S. Royston, Eton-avenue, N.W.
1901. §Calvert, H. T. Roscoe Terrace, Armley, Leeds.
1884. ‡Cameron, Æneas. Yarmouth, Nova Scotia, Canada.
1857. ‡CAMERON, Sir CHARLES A., C.B., M.D. 15 Pembroke-road, Dublin.
1896. §Cameron, Irving H. 307 Sherbourne-street, Toronto, Canada.
1884. ‡Cameron, James C., M.D. 41 Belmont-park, Montreal, Canada.
1870. ‡Cameron, John, M.D. 17 Rodney-street, Liverpool.
1901. §Campbell, Archibald. Springfield Quay, Glasgow.
1884. ‡Campbell, Archibald H. Toronto, Canada.
1876. ‡Campbell, Right Hon. James A., LL.D., M.P. Stracathro House, Brechin.
*Campbell, John Archibald, M.D., F.R.S.E. Albyn-place, Edinburgh.
1897. ‡Campbell, Major J. C. L. New Club, Edinburgh.
1901. §Campbell, M. Pearce. 9 Lynedoch Crescent, Glasgow.
1898. ‡*Campbell, Mrs. Napier. 81 Ashley Gardens, S.W.*
1897. ‡Campion, B. W. Queen's College, Cambridge.

Year of Election.

1882. ‡Candy, F. H. 71 High-street, Southampton.
1890. ‡CANNAN, EDWIN, M.A., F.S.S. 1 Wellington Square, Oxford.
1897. §Cannon, Herbert. Woodbank, Erith, Kent.
1898. ‡CANTERBURY, Right Hon. and Most Rev. F. TEMPLE, Lord Archbishop of. Lambeth Palace, S.E.
1888. ‡Cappel, Sir Albert J. L., K.C.I.E. 27 Kensington Court-gardens, London, W.
1894. §CAPPER, D. S., M.A., Professor of Mechanical Engineering in King's College, W.C.
1883. ‡Capper, Mrs. R. 9 Bridge-street, Westminster, S.W.
1887. ‡CAPSTICK, JOHN WALTON. Trinity College, Cambridge.
1873. *CARBUTT, Sir EDWARD HAMER, Bart., M.Inst.C.E. 19 Hyde Park-gardens, W.
1896. **Carden, H. V. Balinveney, Bookham, Surrey.*
1901. §Cargill, David Sime. 9 Park Terrace, Glasgow.
1877. ‡Carkeet, John. 3 St. Andrew's-place, Plymouth.
1898. ‡Carlile, George M. 7 Upper Belgrave-road, Bristol.
1901. §Carlile, W. Warrand. Harlie, Largs, Ayrshire.
1867. ‡Carmichael, David (Engineer). Dundee.
1876. ‡Carmichael, Niel, M.D. 177 Netherdale Road, Pollokshields, Glasgow.
1897. ‡Carmichael, Norman R. Queen's University, Kingston, Ontario, Canada.
1884. ‡Carnegie, John. Peterborough, Ontario, Canada.
1884. ‡Carpenter, Louis G. Agricultural College, Fort Collins, Colorado, U.S.A.
1897. ‡Carpenter, R. C. Cornell University, Ithaca, New York, U.S.A.
1889. ‡Carr, Cuthbert Ellison. Hedgeley, Alnwick.
1893. ‡CARR, J. WESLEY, M.A., F.L.S., F.G.S., Professor of Biology in University College, Nottingham.
1889. ‡Carr-Ellison, John Ralph. Hedgeley, Alnwick.
1867. ‡CARRUTHERS, WILLIAM, F.R.S., F.L.S., F.G.S. (Pres. D, 1886). 14 Vermont-road, Norwood, S.E.
1886. ‡CARSLAKE, J. BARHAM (Local Sec. 1886). 30 Westfield-road, Birmingham.
1899. §Carslaw, H. S., D.Sc. The University, Glasgow.
1883. ‡Carson, John. 51 Royal-avenue, Belfast.
1868. *Carteighe, Michael, F.C.S., F.I.C. 180 New Bond-street, W.
1897. ‡Carter, E. Tremlett. 'The Electrician,' Salisbury Court, Fleet Street, E.C.
1866. ‡Carter, H. H. The Park, Nottingham.
1870. ‡Carter, Dr. William. 78 Rodney Street, Liverpool.
1883. ‡Carter, W. C. Manchester and Salford Bank, Southport.
1900. *Carter, Rev. W. Lower, F.G.S. Hopton, Mirfield.
1883. ‡Carter, Mrs. Manchester and Salford Bank, Southport.
1896. §Cartwright, Miss Edith G. 21 York Street Chambers, Bryanston Square, W.
1878. *Cartwright, Ernest H., M.A., M.D. 1 Bower Terrace, Maidstone.
1870. §Cartwright, Joshua, M.Inst.C.E., F.S.I., Borough and Water Engineer. Peel Chambers, Market Place, Bury, Lancashire.
1862. ‡Carulla, F. J. R. 84 Argyll-terrace, Derby.
1894. ‡Carus, Paul. La Salle, Illinois, U.S.A.
1884. *Carver, Rev. Canon Alfred J., D.D., F.R.G.S. Lynnhurst, Streatham Common, S.W.
1884. ‡Carver, Mrs. Lynnhurst, Streatham Common, S.W.
1901. §Carver, Thomas A. B., B.Sc., Assoc. M.Inst.C.E. 118 Napiershall Street, Glasgow.

Year of Election.

1887. ‡Casartelli, Rev. L. C., M.A., Ph.D. St. Bede's College, Manchester.
1897. *Case, Willard E. Auburn, New York, U.S.A.
1899. *Case, J. Monckton. Hampden Club, Phœnix-street, N.W.
1896. *Casey, James. 10 Philpot-lane, E.C.
1871. ‡Cash, Joseph. Bird-grove, Coventry.
1873. *Cash, William, F.G.S. 35 Commercial-street, Halifax.
1900. *Cassie, W., M.A. Professor of Physics in the Royal Holloway College, Brantwood, Englefield Green.
1897. †Caston, Harry Edmonds Featherston. 340 Brunswick-avenue, Toronto, Canada.
1874. ‡Caton, Richard, M.D. Lea Hall, Gateacre, Liverpool.
1859. ‡Catto, Robert. 44 King-street, Aberdeen.
1886. *Cave-Moyles, Mrs. Isabella. 4 Crescent Terrace, Cheltenham.
Cayley, Digby. Brompton, near Scarborough.
Cayley, Edward Stillingfleet. Wydale, Malton, Yorkshire.
1883. ‡Chadwick, James Percy. 51 Alexandra-road, Southport.
1859. ‡Chalmers, John Inglis. Aldbar, Aberdeen.
1883. ‡Chamberlain, George, J.P. Helensholme, Birkdale Park, Southport.
1884. ‡Chamberlain, Montague. St. John, New Brunswick, Canada.
1883. ‡Chambers, Mrs. Bombay.
1901. §Chamen, W. A. 66 Partickhill Road, Glasgow.
1881. *Champney, John E. 27 Hans Place, S.W.
1865. ‡Chance, A. M. Edgbaston, Birmingham.
1865. ‡Chance, Robert Lucas. Chad Hill, Edgbaston, Birmingham.
1888. ‡Chandler, S. Whitty, B.A. Sherborne, Dorset.
1861. *Chapman, Edward, M.A., M.P., F.L.S., F.C.S. Hill End, Mottram, Manchester.
1897. ‡Chapman, Edward Henry. 17 St. Hilda's-terrace, Whitby.
1889. ‡Chapman, L. H. 147 Park-road, Newcastle-upon-Tyne.
1884. ‡Chapman, Professor. University College, Toronto, Canada.
1899. §Chapman, Prof. Sydney John. The Owens College, Manchester.
1877. ‡Chapman, T. Algernon, M.D. 17 Wesley-avenue, Liscard, Cheshire.
1874. ‡Charles, J. J., M.D., Professor of Anatomy and Physiology in Queen's College, Cork. Newmarket, Co. Cork.
1874. ‡Charley, William. Seymour Hill, Dunmurry, Ireland.
1886. ‡Chate, Robert W. Southfield, Edgbaston, Birmingham.
1884. *Chatterton, George, M.A., M.Inst.C.E. 6 The Sanctuary, Westminster, S.W.
1886. *Chattock, A. P., M.A., Professor of Experimental Physics in University College, Bristol.
1867. *Chatwood, Samuel, F.R.G.S. High Lawn, Broad Oak Park, Worsley, Manchester.
1884. ‡Chauveau, The Hon. Dr. Montreal, Canada.
1883. ‡Chawner, W., M.A. Emmanuel College, Cambridge.
1864. ‡Cheadle, W. B., M.A., M.D., F.R.G.S. 19 Portman-street, Portman-square, W.
1900. §Cheesman, W. Norwood. The Crescent, Selby.
1887. ‡Cheetham, F. W. Limefield House, Hyde.
1887. ‡Cheetham, John. Limefield House, Hyde.
1896. ‡Chenie, John. Charlotte-street, Edinburgh.
1874. *Chermside, Major-General Sir H. C., R.E., G.C.M.G., C.B. Care of Messrs. Cox & Co., Craig's-court, Charing Cross, S.W.
1884. ‡Cherriman, Professor J. B. Ottawa, Canada.
1896. ‡Cherry, R. B. 92 Stephen's Green, Dublin.
1879. *Chesterman, W. Belmayne, Sheffield.
1883. †Chinery, Edward F. Monmouth House, Lymington.

Year of Election.

1884. †Chipman, W. W. L. 957 Dorchester-street, Montreal, Canada.
1889. ‡Chirney, J. W., Morpeth.
1894. †CHISHOLM, G. G., M.A., B.Sc., F.R.G.S. 59 Drakefield Road, Upper Tooting, S.W.
1900. ‡CHISHOLM, SAMUEL, Lord Provost of Glasgow.
1899. §Chitty, Edward. Sonnenberg, Castle Avenue, Dover.
1899. §Chitty, Mrs. Edward. Sonnenberg, Castle Avenue, Dover.
1899. §Chitty, G. W. Mildura, Park-avenue, Dover.
1882. ‡Chorley, George. Midhurst, Sussex.
1887. ‡Chorlton, J. Clayton. New Holme, Withington, Manchester.
1893. *CHREE, CHARLES, D.Sc., F.R.S. Kew Observatory, Richmond, Surrey.
1900. *Christie, R. J. Duke Street, Toronto, Canada.
1884. *Christie, William. 29 Queen's Park, Toronto, Canada.
1875. *Christopher, George, F.C.S. May Villa, Lucien-road, Tooting Common, S.W.
1876. *CHRYSTAL, GEORGE, M.A., LL.D., F.R.S.E. (Pres. A, 1885), Professor of Mathematics in the University of Edinburgh. 5 Belgrave-crescent, Edinburgh.
1870. §CHURCH, A. H., M.A., F.R.S., F.S.A., Professor of Chemistry in the Royal Academy of Arts. Shelsley, Ennerdale-road, Kew.
1898. §CHURCH, Colonel G. EARL, F.R.G.S. (Pres. E, 1898). 216 Cromwell-road, S.W.
1860. ‡CHURCH, Sir WILLIAM SELBY, Bart., M.D. St. Bartholomew's Hospital, E.C.
1896. ‡Clague, Daniel, F.G.S. 5 Sandstone-road, Stoneycroft, Liverpool.
1901. §Clark, Archibald B., M.A. 2 Woodburn Place, Edinburgh.
1890. ‡Clark, E. K. 13 Wellclose-place, Leeds.
1877. *Clark, F. J., J.P., F.L.S. Netherleigh, Street, Somerset.
Clark, George T. 44 Berkeley-square, W.
1876. ‡Clark, David R., M.A. 8 Park Drive West, Glasgow.
1892. ‡*Clark, James, M.A., Ph.D., Professor of Agriculture in the Yorkshire College, Leeds.*
1892. ‡Clark, James. Chapel House, Paisley.
1901. §Clark, James M., M.A., B.Sc. 8 Park Drive West, Glasgow.
1876. ‡Clark, Dr. John. 138 Bath-street, Glasgow.
1881. ‡Clark, J. Edmund, B.A., B.Sc. 112 Wool Exchange, E.C.
1901. §Clark, Robert M., B.Sc., F.L.S. 27 Albyn Place, Aberdeen.
1855. ‡Clark, Rev. William, M.A. Barrhead, near Glasgow.
1887. §Clarke, C. Goddard, J.P. Fairlawn, 157 Peckham-rye, S.E.
1875. ‡Clarke, Charles S. 4 Worcester-terrace, Clifton, Bristol.
1886. ‡Clarke, David. Langley-road, Small Heath, Birmingham.
1886. ‡Clarke, Rev. H. J. Great Barr Vicarage, Birmingham.
1875. ‡CLARKE, JOHN HENRY (Local Sec. 1875). 4 Worcester-terrace, Clifton, Bristol.
1897. §Clarke, Colonel S. C., R.E. Parklands, Caversham, near Reading.
1883. ‡Clarke, W. P., J.P. 15 Hesketh-street, Southport.
1896. ‡Clarke, W. W. Albert Dock Office, Liverpool.
1884. ‡Claxton, T. James. 461 St. Urbain-street, Montreal, Canada.
1889. §CLAYDEN, A. W., M.A., F.G.S. St. John's, Polsloe-road, Exeter.
1866. ‡Clayden, P. W. 13 Tavistock-square, W.C.
1890. *Clayton, William Wikely. Gipton Lodge, Leeds.
1859. ‡Cleghorn, John. Wick.
1861. §CLELAND, JOHN, M.D., D.Sc., F.R.S., Professor of Anatomy in the University of Glasgow. 2 The University, Glasgow.
1861. *CLIFTON, R. BELLAMY, M.A., F.R.S., F.R.A.S., Professor of Experimental Philosophy in the University of Oxford. 3 Bardwell-road, Banbury-road, Oxford.

Year of Election.

1898. ‡Clissold, H. 30 College-road, Clifton, Bristol.
1893. ‡Clofford, William. 36 Mansfield-road, Nottingham.
Clonbrock, Lord Robert. Clonbrock, Galway.
1878. §Close, Rev. Maxwell H., F.G.S. 38 Lower Baggot-street, Dublin.
1873. ‡Clough, John. Bracken Bank, Keighley, Yorkshire.
1892. ‡Clouston, T. S., M.D. Tipperlinn House, Edinburgh.
1883. *CLOWES, FRANK, D.Sc., F.C.S. (Local Sec. 1893). London County Council, Spring-gardens, S.W., and 17 Bedford Court-mansions, W.C.
1881. *Clutton, William James. The Mount, York.
1885. ‡Clyne, James. Rubislaw Den South, Aberdeen.
1891. *Coates, Henry. Pitcullen House, Perth.
1897. ‡Coates, J., M.Inst.C.E. 99 Queen-street, Melbourne, Australia.
1901. §Coats, Allan. Hayfield, Paisley.
1884. §Cobb, John. Westfield, Ilkley, Yorkshire.
1895. *COBBOLD, FELIX T., M.A. The Lodge, Felixstowe, Suffolk.
1889. ‡Cochrane, Cecil A. Oakfield House, Gosforth, Newcastle-upon-Tyne.
1864. *Cochrane, James Henry. Burston House, Pittville, Cheltenham.
1889. ‡Cochrane, William. Oakfield House, Gosforth, Newcastle-upon-Tyne.
1892. ‡Cockburn, John. Glencorse House, Milton Bridge, Edinburgh.
1901. §Cockburn, Sir John, K.C.M.G., M.D. 10 Gatestone Road, Upper Norwood, S.E.
1883. ‡Cockshott, J. J. 24 Queen's-road, Southport.
1861. *Coe, Rev. Charles C., F.R.G.S. Whinsbridge, Grosvenor-road, Bournemouth.
1898. ‡Coffey, George. 5 Harcourt-terrace, Dublin.
1881. *COFFIN, WALTER HARRIS, F.C.S. 94 Cornwall-gardens, South Kensington, S.W.
1896. *Coghill, Percy de G. 4 Sunnyside, Prince's Park, Liverpool.
1884. *Cohen, B. L., M.P. 30 Hyde Park-gardens, W.
1887. ‡Cohen, Julius B. Yorkshire College, Leeds.
1901 §Cohen, N. L. 11 Hyde Park Terrace, W.
1901. *Cohen, R. Waley. 11 Hyde Park Terrace, W.
1894. *Colby, Miss E. L., B.A. Carregwen, Aberystwyth.
1895. *Colby, James George Ernest, M.A., F.R.C.S. Malton, Yorkshire.
1895. *Colby William Henry. Carregwen, Aberystwyth.
1893. ‡Cole, Prof. Grenville A. J., F.G.S. Royal College of Science, Dublin.
1879. ‡Cole, Skelton. 387 Glossop-road, Sheffield.
1864. ‡Colefax, H. Arthur, Ph.D., F.C.S. 14 Chester-terrace, Chester-square, S.W.
1897. §COLEMAN, Dr. A. P. 476 Huron-street, Toronto, Canada.
1893. ‡Coleman, J. B., F.C.S., A.R.C.S. University College, Nottingham.
1899. §Coleman, William. The Shrubbery, Buckland, Dover.
1878. ‡Coles, John. 1 Savile-row, W.
1854. *Colfox, William, B.A. Westmead, Bridport, Dorsetshire.
1899. §Collard, George. The Gables, Canterbury.
1892. ‡Collet, Miss Clara E. 7 Coleridge-road, N.
1892. ‡Collie, Alexander. Harlaw House, Inverurie.
1887. ‡COLLIE, J. NORMAN, Ph.D., F.R.S., Professor of Chemistry to the Pharmaceutical Society of Great Britain. 16 Campden-grove, W.
1869. ‡Collier, W. F. Woodtown, Horrabridge, South Devon.
1893. ‡Collinge, Walter E. The University, Birmingham.
1854. ‡COLLINGWOOD, CUTHBERT, M.A., M.B., F.L.S. 69 Great Russell-street, W.C.
1861. *Collingwood, J. Frederick, F.G.S. 5 Irene-road, Parson's Green, S.W.
1876. ‡COLLINS, J. H., F.G.S. 162 Barry-road, S.E.

Year of Election.

1865. *Collins, James Tertius. Churchfield, Edgbaston, Birmingham.
1882. ‡Colmer, Joseph G., C.M.G. Office of the High Commissioner for Canada, 17 Victoria-street, S.W.
1884. ‡Colomb, Sir J. C. R., M.P., F.R.G.S. Dromquinna, Kenmare, Kerry, Ireland; and Junior United Service Club, S.W.
1897. ‡Colquhoun, A. H. U., B.A. 39 Borden-street, Toronto, Canada.
1896. *Comber, Thomas, F.L.S. Leighton, Parkgate, Chester.
1888. ‡Commans, R. D. Macaulay-buildings, Bath.
1884. ‡COMMON, A. A., LL.D., F.R.S., F.R.A.S. 63 Eaton-rise, Ealing, W.
1891. ‡Common, J. F. F. 21 Park-place, Cardiff.
1900. ‡Common, T. A., B.A. 63 Eaton Rise, Ealing, W.
1892. ‡Comyns, Frank, M.A., F.C.S. The Grammar School, Durham.
1884. ‡Conklin, Dr. William A. Central Park, New York, U.S.A.
1896. ‡Connacher, W. S. Birkenhead Institute, Birkenhead.
1890. ‡Connon, J. W. Park-row, Leeds.
1871. *Connor, Charles C. 4 Queen's Elms, Belfast.
1893. ‡CONWAY, Professor Sir W. M., M.A., F.R.G.S. The Red House, Hornton-street, W.
1899. ‡COODE, J. CHARLES, M.Inst.C.E. Westminster-chambers, 9 Victoria-street, S.W.
1898. §Cook, Ernest H. 27 Berkeley-square, Clifton, Bristol.
1900. ‡Cook, Walter. 98 St. Mary's Street, Cardiff.
1882. ‡COOKE, Major-General A. C., R.E., C.B., F.R.G.S. Palace-chambers, Ryder-street, S.W.
1876. *COOKE, CONRAD W. 28 Victoria-street, S.W.
1881. ‡Cooke, F. Bishopshill, York.
1868. ‡Cooke, Rev. George H. Wanstead Vicarage, near Norwich.
1895. ‡*Cooke, Miss Janette E. Holmwood, Thorpe, Norwich.*
1868. ‡COOKE, M. C., M.A. 53 Castle Road, Kentish Town, N.W.
1884. ‡Cooke, R. P. Brockville, Ontario, Canada.
1878. ‡*Cooke, Samuel, M.A., F.G.S. Poona, Bombay.*
1881. ‡Cooke, Thomas. Bishopshill, York.
1865. ‡Cooksey, Joseph. West Bromwich, Birmingham.
1896. ‡Cookson, E. H. Kiln Hey, West Derby.
1899. *Coomara Swamy, A. K., F.G.S. Walden, Worplesdon, Guildford.
1895. ‡Cooper, Charles Friend, M.I.E.E. 68 Victoria-street, Westminster, S.W.
1901. *Cooper, C. Forster, B.A. Trinity College, Cambridge.
1893. ‡Cooper, F. W. 14 Hamilton-road, Sherwood Rise, Nottingham.
1883. ‡*Cooper, George B. 67 Great Russell-street, W.C.*
1868. ‡Cooper, W. J. New Malden, Surrey.
1889. ‡Coote, Arthur. The Minories, Jesmond, Newcastle-upon-Tyne.
1878. ‡Cope, Rev. S. W. Bramley, Leeds.
1871. ‡COPELAND, RALPH, Ph.D., F.R.A.S., Astronomer Royal for Scotland and Professor of Astronomy in the University of Edinburgh.
1881. ‡Copperthwaite, H. Holgate Villa, Holgate-lane, York.
1901. §Corbett, A. Cameron, M.P. Thornliebank House, Glasgow.
1891. ‡Corbett, E. W. M. Y Fron, Pwllypant, Cardiff.
1887. *Corcoran, Bryan. Fairlight, 22 Oliver Grove, South Norwood, S.E.
1894. §Corcoran, Miss Jessie R. The Chestnuts, Mulgrave-road, Sutton, Surrey.
1883. *Core, Professor Thomas H., M.A. Fallowfield, Manchester.
1870. *CORFIELD, W. H., M.A., M.D., F.C.S., F.G.S., Professor of Hygiene and Public Health in University College, London. 19 Savile-row, W.
1901. *Cormack, Professor J. D., B.Sc. University College, Gower-street, W.C.

Year of Election.

1893. *Corner, Samuel, B.A., B.Sc. 95 Forest-road West, Nottingham.
1889. ‡CORNISH, VAUGHAN, M.Sc., F.R.G.S. 72 Prince's Square, W.
1884. *Cornwallis, F. S. W., M.P., F.L.S. Linton Park, Maidstone.
1885. ‡Corry, John. Rosenheim, Park Hill-road, Croydon.
1888. ‡Corser, Rev. Richard K. 57 Park Hill-road, Croydon.
1900. §Cortie, Rev. A. L., F.R.A.S. Stonyhurst College, Blackburn.
1891. ‡Cory, John, J.P. Vaindre Hall, near Cardiff.
1891. ‡Cory, Alderman Richard, J.P. Oscar House, Newport-road, Cardiff.
1891. *Cotsworth, Haldane Gwilt. The Cedars, Cobham Road, Norbiton, S.W.
1874. *COTTERILL, J. H., M.A., F.R.S. 15 St. Alban's-mansions, Kensington Court-gardens, W.
1869. ‡*COTTON, WILLIAM. Pennsylvania, Exeter.*
1876. ‡Couper, James. City Glass Works, Glasgow.
1876. ‡Couper, James, jun. City Glass Works, Glasgow.
1889. ‡*Courtney, F. S. 77 Redcliffe-square, South Kensington, S.W.*
1896. ‡COURTNEY, Right Hon. LEONARD (Pres. F, 1896). 15 Cheyne Walk, Chelsea, S.W.
1890. ‡Cousins, John James. Allerton Park, Chapel Allerton, Leeds.
1896. ‡Coventry, J. 19 Sweeting-street, Liverpool.
Cowan, John. Valleyfield, Pennycuick, Edinburgh.
1863. ‡Cowan, John A. Blaydon Burn, Durham.
1863. ‡Cowan, Joseph, jun. Blaydon, Durham.
1872. *Cowan, Thomas William, F.L.S., F.G.S. 17 King William-street, Strand, W.C.
1900. §Cowburn, Henry. Dingle Head, Westleigh, Leigh, Lancashire.
1895. *COWELL, PHILIP H., M.A. Royal Observatory, Greenwich, and 74 Vanbrugh Park, Blackheath, S.E.
1899. §Cowper-Coles, Sherard. 82 Victoria-street, S.W.
1867. *Cox, Edward. Cardean, Meigle, N.B.
1892. ‡Cox, Robert. 34 Drumsheugh-gardens, Edinburgh.
1882. ‡Cox, Thomas A., District Engineer of the S., P., and D. Railway, Lahore, Punjab. Care of Messrs. Grindlay & Co., Parliament-street, S.W.
1888. ‡Cox, Thomas W. B. The Chestnuts, Lansdowne, Bath.
1867. ‡Cox, William. Foggley, Lochee, by Dundee.
1883. ‡Crabtree, William. 126 Manchester-road, Southport.
1890. ‡Cradock, George. Wakefield.
1892. *Craig, George A. Post-office, Mooroopna, Victoria, Australia.
1884. §CRAIGIE, Major P. G., F.S.S. (Pres. F, 1900). 6 Lyndhurst-road, Hampstead, N.W.
1876. ‡Cramb, John. Larch Villa, Helensburgh, N.B.
1884. ‡Crathern, James. Sherbrooke-street, Montreal, Canada.
1887. ‡Craven, John. Smedley Lodge, Cheetham, Manchester.
1887. *Craven, Thomas, J.P. Woodheyes Park, Ashton-upon-Mersey.
1871. *CRAWFORD AND BALCARRES, The Right Hon. the Earl of, K.T., LL.D., F.R.S., F.R.A.S. 2 Cavendish Square, W., and Haigh Hall, Wigan.
1871. *Crawford, William Caldwell, M.A. 1 Lockharton-gardens, Colinton Road, Edinburgh.
1846. *Crawshaw, The Right Hon. Lord. Whatton, Loughborough.
1890. §Crawshaw, Charles B. Rufford Lodge, Dewsbury.
1883. *Crawshaw, Edward, F.R.G.S. 25 Tollington-park, N.
1870. *Crawshay, Mrs. Robert. Caversham Park, Reading.
1885. §CREAK, Captain E. W., R.N., C.B., F.R.S. (Council 1896–). 9 Hervey-road, Blackheath, S.E.

Year of Election.

1901. §Cree, T. S. 15 Montgomerie Quadrant, Glasgow.
1896. ‡Cregeen, A. G. 21 Prince's-avenue, Liverpool.
1879. ‡Creswick, Nathaniel. Chantry Grange, near Sheffield.
1876. *Crewdson, Rev. Canon George. St. Mary's Vicarage, Windermere.
1887. *Crewdson, Theodore. Norcliffe Hall, Handforth, Manchester.
1896. §Crichton, Hugh. 6 Rockfield-road, Anfield, Liverpool.
1880. *Crisp, Frank, B.A., LL.B., F.L.S., F.G.S. 5 Lansdowne-road, Notting Hill, W.
1890. *Croft, W. B., M.A. Winchester College, Hampshire.
1878. ‡Croke, John O'Byrne, M.A. Clouneagh, Ballingarry-Lacy, co. Limerick.
1857. ‡Crolly, Rev. George. Maynooth College, Ireland.
1885. ‡CROMBIE, J. W., M.A., M.P. (Local Sec. 1885). Balgownie Lodge, Aberdeen.
1885. ‡Crombie, Theodore. 18 Albyn-place, Aberdeen.
1901.§§CROMPTON, Col., R.E., M.Inst.C.E. (Pres. G, 1901). Kensington Court, W.
1887. §CROOK, HENRY T., M.Inst.C.E. 9 Albert-square, Manchester.
1898. §Crooke, William. Langton House, Charlton Kings, Cheltenham.
1865. §CROOKES, Sir WILLIAM, F.R.S., V.P.C.S. (PRESIDENT, 1898; Pres. B, 1886; Council 1885-91). 7 Kensington Park-gardens, W.
1879. ‡Crookes, Lady. 7 Kensington Park-gardens, W.
1897. *CROOKSHANK, E. M., M.B. Ashdown Forest.
1870. ‡Crosfield, C. J. Gledhill, Sefton Park, Liverpool.
1894. *Crosfield, Miss Margaret C. Undercroft, Reigate.
1870. *CROSFIELD, WILLIAM. 3 Fulwood Park, Liverpool.
1890. ‡Cross, E. Richard, LL.B. Harwood House, New Parks-crescent, Scarborough.
1861. ‡*Cross, Rev. John Edward, M.A., F.G.S. Halecote, Grange-over-Sands.*
1853. ‡Crosskill, William. Beverley, Yorkshire.
1887. *Crossley, William J. Glenfield, Bowdon, Cheshire.
1894. *Crosweller, William Thomas, F.Z.S., F.I.Inst. Kent Lodge, Sidcup, Kent.
1897. *Crosweller, Mrs. W. T. Kent Lodge, Sidcup, Kent.
1894. ‡*Crow, C. F. Home Lea, Woodstock Road, Oxford.*
1883. ‡Crowder, Robert. Stanwix, Carlisle.
1882. §Crowley, Frederick. Ashdell, Alton, Hampshire.
1890. *Crowley, Ralph Henry, M.D. 116 Manningham Lane, Bradford.
1863. ‡Cruddas, George. Elswick Engine Works, Newcastle-upon-Tyne.
1885. ‡Cruickshank, Alexander, LL.D. 20 Rose-street, Aberdeen.
1888. ‡Crummack, William J. London and Brazilian Bank, Rio de Janeiro, Brazil.
1898. ‡CRUNDALL, Sir WILLIAM H. Dover.
1888. ‡Culley, Robert. Bank of Ireland, Dublin.
1883. *CULVERWELL, EDWARD P., M.A. 40 Trinity College, Dublin.
1878. ‡Culverwell, Joseph Pope. St. Lawrence Lodge, Sutton, Dublin.
1883. ‡Culverwell, T. J. H. Litfield House, Clifton, Bristol.
1897. ‡Cumberland, Barlow. Toronto, Canada.
1898. §Cundall, J. Tudor. 1 Dean Park-crescent, Edinburgh.
1861. *Cunliffe, Edward Thomas. The Parsonage, Handforth, Manchester.
1861. *Cunliffe, Peter Gibson. Dunedin, Handforth, Manchester.
1882. *CUNNINGHAM, Lieut.-Colonel ALLAN, R.E., A.I.C.E. 20 Essex-villas, Kensington, W.

Year of Election.

1877. *CUNNINGHAM, D. J., M.D., D.C.L., F.R.S., F.R.S.E. (Pres. H, 1901), Professor of Anatomy in Trinity College. 43 Fitzwilliam Place, Dublin.
1891. ‡Cunningham, J. H. 2 Ravelston Place, Edinburgh.
1852. ‡Cunningham, John. Macedon, near Belfast.
1885. ‡CUNNINGHAM, J. T., B.A. Biological Laboratory, Plymouth.
1869. ‡CUNNINGHAM, ROBERT O., M.D., F.L.S., F.G.S., Professor of Natural History in Queen's College, Belfast.
1883. *CUNNINGHAM, Rev. W. (Pres. F, 1891), D.D., D.Sc. Trinity College, Cambridge.
1892. §Cunningham-Craig, E. H., B.A., F.G.S. Geological Survey Office, Sheriff Court-buildings, Edinburgh.
1900. *Cunnington, W. Alfred. 13 The Chase, Clapham Common, S.W.
1892. *Currie, James, jun., M.A., F.R.S.E. Larkfield, Golden Acre, Edinburgh.
1884. ‡Currier, John McNab. Newport, Vermont, U.S.A.
1898. ‡Curtis, John. 1 Christchurch-road, Clifton, Bristol.
1878. ‡Curtis, William. Caramore, Sutton, Co. Dublin.
1884. ‡Cushing, Frank Hamilton. Washington, U.S.A.
1883. ‡Cushing, Mrs. M. Croydon, Surrey.
1881. §Cushing, Thomas, F.R.A.S. India Store Depôt, Belvedere-road, Lambeth, S.W.

1889. ‡Dagger, John H., F.I.C. Victoria Villa, Lorne-street, Fairfield, Liverpool.
1854. ‡Daglish, Robert. Orrell Cottage, near Wigan.
1883. ‡Dähne, F. W., Consul of the German Empire. 18 Somerset-place, Swansea.
1898. §Dalby, Prof. W. E., B.Sc., M.Inst.C.E. 6 Coleridge-road, Crouch End, N.
1889. *Dale, Miss Elizabeth. 2 Trumpington Street, Cambridge.
1863. ‡Dale, J. B. South Shields.
1867. ‡Dalgleish, W. Dundee.
1870. ‡DALLINGER, Rev. W. H., D.D., LL.D., F.R.S., F.L.S. Ingleside, Newstead-road, Lee, S.E.
Dalton, Edward, LL.D. Dunkirk House, Nailsworth.
1862. ‡DANBY, T. W., M.A., F.G.S. The Crouch, Seaford, Sussex.
1901. §Daniell, G. F., B.Sc. 44 Cavendish Road, Brondesbury, N.W.
1876. *Dansken, John, F.R.A.S. 2 Hillside Gardens, Partickhill, Glasgow.
1896. §Danson, F. C. Liverpool and London Chambers, Dale-street, Liverpool.
1849. *Danson, Joseph, F.C.S. Montreal, Canada.
1894. ‡Darbishire, B. V., M.A., F.R.G.S. 1 Savile-row, W.
1897. ‡Darbishire, C. W. Elm Lodge, Elm-row, Hampstead, N.W.
1897. §Darbishire, F. V., B.A., Ph.D. Hulme Hall, Plymouth Grove, and Owens College, Manchester.
1861. *DARBISHIRE, ROBERT DUKINFIELD, B.A. (Local Sec. 1861). Victoria Park, Manchester.
1896. ‡Darbishire, W. A. Penybryn, Carnarvon, North Wales.
1899. *Darwin, Erasmus. The Orchard, Huntingdon-road, Cambridge.
1882. ‡DARWIN, FRANCIS, M.A., M.B., F.R.S., F.L.S. (Pres. D, 1891; Council 1882–84, 1897–1901). Wychfield, Huntingdon-road, Cambridge.
1881. *DARWIN, GEORGE HOWARD, M.A., LL.D., F.R.S., F.R.A.S. (Pres. A, 1886; Council 1886–92), Plumian Professor of Astronomy and Experimental Philosophy in the University of Cambridge. Newnham Grange, Cambridge.

Year of Election.

1878. *Darwin, Horace. The Orchard, Huntingdon-road, Cambridge.
1894. *Darwin, Major Leonard, Hon. Sec. R.G.S. (Pres. E, 1896; Council 1899–). 12 Egerton-place, South Kensington, S.W.
1882. ‡Darwin, W. E., M.A., F.G.S. Bassett, Southampton.
1888. ‡Daubeny, William M. 11 St. James's-square, Bath.
1880. *Davey, Henry, M.Inst.C.E., F.G.S. 3 Prince's-street, Westminster, S.W.
1898. §Davey, William John. 6 Water-street, Liverpool.
1884. ‡David, A. J., B.A., LL.B. 4 Harcourt-buildings, Temple, E.C.
1870. ‡Davidson, Alexander, M.D. 2 Gambier-terrace, Liverpool.
1885. ‡Davidson, Charles B. Roundhay, Fonthill-road, Aberdeen.
1891. ‡Davies, Andrew, M.D. Cefn Parc, Newport, Monmouthshire.
1870. ‡Davies, Edward, F.C.S. Royal Institution, Liverpool.
1887. *Davies, H. Rees. Treborth, Bangor, North Wales.
1896. *Davies, Thomas Wilberforce, F.G.S. 41 Park-place, Cardiff.
1893. *Davies, Rev. T. Witton, B.A., Ph.D. Bryn Haul, and Baptist College, Bangor.
1898. ‡Davies, Wm. Howell, J.P. Down House, Stoke Bishop, Bristol.
1873. *Davis, Alfred. 37 Ladbroke Grove, W.
1870. *Davis, A. S. St. George's School, Roundhay, near Leeds.
1864. ‡Davis, Charles E., F.S.A. (Local Sec. 1864). 55 Pulteney-street, Bath.
1882. ‡Davis, Henry C. Berry Pomeroy, Springfield-road, Brighton.
1896. *Davis, John Henry Grant. Valindra, Wood Green, Wednesbury, Staffordshire.
1885. *Davis, Rev. Rudolf. Hopefield, Evesham.
1886. ‡Davis, W. H. Hazeldean, Pershore-road, Birmingham.
1886. ‡Davison, Charles, D.Sc. 16 Manor-road, Birmingham.
1864. *Davison, Richard. Beverley-road, Great Driffield, Yorkshire.
1857. ‡Davy, E. W., M.D. Kimmage Lodge, Roundtown, Dublin.
1869. ‡Daw, John. Mount Radford, Exeter.
1869. ‡Daw, R. R. M. Bedford-circus, Exeter.
1860. *Dawes, John T. The Lilacs, Prestatyn, North Wales.
1864. ‡Dawkins, W. Boyd, D.Sc., F.R.S., F.S.A., F.G.S. (Pres. C, 1888; Council 1882–88), Professor of Geology and Palæontology in the Victoria University, Owens College, Manchester. Woodhurst, Fallowfield, Manchester.
1886. ‡Dawson, Bernard. The Laurels, Malvern Link.
1891. ‡Dawson, Edward. 2 Windsor-place, Cardiff.
1885. *Dawson, Lieut.-Colonel H. P., R.A. Hartlington, Burnsall, Skipton.
1901. §Dawson, P. 11 Campside Crescent, Langside, Glasgow.
1884. ‡Dawson, Samuel (Local Sec. 1884). 258 University Street, Montreal, Canada.
1859. *Dawson, Captain William G. The Links, Plumstead Common, Kent.
1892. ‡Day, T. C., F.C.S. 36 Hillside-crescent, Edinburgh.
1870. *Deacon, G. F., M.Inst.C.E. (Pres. G, 1897). 19 Warwick-square, S.W.
1900. §Deacon, M. Whittington House, near Chesterfield.
1887. ‡Deakin, H. T. Egremont House, Belmont, near Bolton.
1861. ‡Dean, Henry. Colne, Lancashire.
1901. *Deasy, Capt. H. H. P. Cavalry Club, Piccadilly, W.
1884. *Debenham, Frank, F.S.S. 1 Fitzjohn's-avenue, N.W.
1866. ‡Debus, Heinrich, Ph.D., F.R.S., F.C.S. (Pres. B, 1869; Council 1870–75). 4 Schlangenweg, Cassel, Hessen.
1884. ‡Deck, Arthur, F.C.S. 9 King's-parade, Cambridge.
1893. ‡Deeley, R. M. 38 Charnwood-street, Derby.
1878. ‡Delany, Rev. William. St. Stanislaus College, Tullamore.

Year of
Election.

1896. §Dempster, John. Tynron, Noctorum, Birkenhead.
1889. ‡Dendy, Frederick Walter. 3 Mardale-parade, Gateshead.
1897. §Denison, F. Napier. Meteorological Office, Victoria, B.C., Canada.
1896. ‡Denison, Miss Louisa E. 16 Chesham-place, S.W.
1889. §DENNY, ALFRED, F.L.S., Professor of Biology in University College, Sheffield.
Dent, William Yerbury. 5 Caithness-road, Brook Green, W.
1874. ‡DE RANCE, CHARLES E., F.G.S. 33 Carshalton Road, Blackpool.
1896. ‡DERBY, The Right Hon. the Earl of, G.C.B. Knowsley, Prescot, Lancashire.
1874. *Derham, Walter, M.A., LL.M., F.G.S. 76 Lancaster-gate, W.
1894. *Deverell, F. H. 7 Grote's-place, Blackheath, S.E.
1899. ‡DEVONSHIRE, The Duke of, K.G., D.C.L., F.R.S. 78 Piccadilly, W.
1899. ‡Dewar, A. Redcote. Redcote, Leven, Fife.
1868. *DEWAR, JAMES, M.A., LL.D., F.R.S., F.R.S.E., V.P.C.S., Fullerian Professor of Chemistry in the Royal Institution, London, and Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge (PRESIDENT ELECT; Pres. B, 1879; Council 1883–88). 1 Scroope-terrace, Cambridge.
1881. ‡Dewar, Mrs. 1 Scroope-terrace, Cambridge.
1883. ‡Dewar, James, M.D., F.R.C.S.E. Drylaw House, Davidson's Mains, Midlothian, N.B.
1884. *Dewar, William, M.A. Horton House, Rugby.
1872. ‡Dewick, Rev. E. S., M.A., F.G.S. 26 Oxford-square, W.
1887. ‡DE WINTON, Major-General Sir F., G.C.M.G., C.B., D.C.L., LL.D., F.R.G.S. (Pres. E, 1899). United Service Club, Pall Mall, S.W.
1884. ‡De Wolf, O. C., M.D. Chicago, U.S.A.
1873. *DEW-SMITH, A. G., M.A. Chesterton Hall, Cambridge.
1896. ‡D'Henry, P. 136 Prince's-road, Liverpool.
1897. ‡Dick, D. B. Toronto, Canada.
1901. §Dick, George H. 31 Hamilton Drive, Hillhead, Glasgow.
1901. §Dick, Thomas. Lockhead House, Pollokshields, Glasgow.
1889. ‡Dickinson, A. H. The Wood, Maybury, Surrey.
1863. ‡Dickinson, G. T. Lily-avenue, Jesmond, Newcastle-upon-Tyne.
1887. ‡Dickinson, Joseph, F.G.S. South Bank, Pendleton.
1884. ‡Dickson, Charles R., M.D. Wolfe Island, Ontario, Canada.
1881. ‡Dickson, Edmund, M.A., F.G.S. 2 Starkie-street, Preston.
1887. §DICKSON, H. N., B.Sc., F.R.S.E., F.R.G.S. 2 St. Margaret's-road, Oxford.
1885. ‡Dickson, Patrick. Laurencekirk, Aberdeen.
1883. ‡*Dickson, T. A. West Cliff, Preston.*
1862. *DILKE, The Right Hon. Sir CHARLES WENTWORTH, Bart., M.P., F.R.G.S. 76 Sloane-street, S.W.
1877. ‡Dillon, James, M.Inst.C.E. 36 Dawson-street, Dublin.
1901. §Dines, W. H. Crinan, N.B.
1869. ‡Dingle, Edward. 19 King-street, Tavistock.
1900. §DIVERS, Dr. EDWARD, F.R.S. 9 Rugby Mansions, Kensington, W.
1898. *Dix, John William S. Hampton Lodge, Durdham Park, Clifton, Bristol.
1899 *DIXON, A. C., D.Sc., Professor of Mathematics in Queen's College, Galway.
1874. *DIXON, A. E., M.D., Professor of Chemistry in Queen's College, Cork. Mentone Villa, Sunday's Well, Cork.
1900. §Dixon, A. Francis, D.Sc., Professor of Anatomy in University College, Cardiff.
1883. ‡Dixon, Miss E. 2 Cliff-terrace, Kendal.

Year of
Election.

1888. §Dixon, Edward T. Racketts, Hythe, Hampshire.
1900. *Dixon, George, M.A. St. Bees, Cumberland.
1879. *DIXON, HAROLD B., M.A., F.R.S., F.C.S. (Pres. B, 1894), Professor of Chemistry in the Owens College, Manchester.
1885. ‡Dixon, John Henry. Inveran, Poolewe, Ross-shire, N.B.
1896. §Dixon-Nuttall, F. R. Ingleholme, Ecclestone Park, Prescot.
1887. ‡Dixon, Thomas. Buttershaw, near Bradford, Yorkshire.
1885. ‡Doak, Rev. A. 15 Queen's-road, Aberdeen.
1890. ‡Dobbie, James J., D.Sc. Professor of Chemistry, University College, Bangor, North Wales.
1885. §Dobbin, Leonard, Ph.D. The University, Edinburgh.
1860. *Dobbs, Archibald Edward, M.A. Hartley Manor, Longfield, Kent.
1897. ‡Doberck, William. The Observatory, Hong Kong.
1892. ‡Dobie, W. Fraser. 47 Grange-road, Edinburgh.
1891. ‡Dobson, G. Alkali and Ammonia Works, Cardiff.
1893. ‡Dobson, W. E., J.P. Lenton-road, The Park, Nottingham.
1875. *Docwra, George. 19 Clarence Street, Gloucester.
1870. *Dodd, John. Nunthorpe-avenue, York.
1876. ‡Dodds, J. M. St. Peter's College, Cambridge.
1897. †Dodge, Richard E. Teachers' College, Columbia University, New York, U.S.A.
1889. ‡Dodson, George, B.A. Downing College, Cambridge.
1898. ‡Dole, James. Redland House, Bristol.
1893. ‡Donald, Charles W. Kinsgarth, Braid-road, Edinburgh.
1885. †Donaldson, James, M.A., LL.D., F.R.S.E., Senior Principal of the University of St. Andrews, N.B.
1869. ‡Donisthorpe, G. T. St. David's Hill, Exeter.
1877. *DONKIN, BRYAN, M.Inst.C.E. The Mount, Wray Park, Reigate.
1889. ‡Donkin, R. S., M.P. Campville, North Shields.
1896. ‡Donnan, F. E. Ardenmore-terrace, Holywood, Ireland.
1901. §Donnan, F. G. University College, Gower Street, W.C.
1861. ‡Donnelly, Major-General Sir J. F. D., R.E., K.C.B. 59 Onslow-gardens, S.W.
1881. ‡Dorrington, John Edward. Lypiatt Park, Stroud.
1867. ‡Dougall, Andrew Maitland, R.N. Scotscraig, Tayport, Fifeshire.
1863. *Doughty, Charles Montagu. Illawara House, Tunbridge Wells.
1884. ‡Douglass, William Alexander. Freehold Loan and Savings Company, Church-street, Toronto, Canada.
1890. ‡Dovaston, John. West Felton, Oswestry.
1883. ‡Dove, Arthur. Crown Cottage, York.
1884. ‡Dove, Miss Frances. St. Leonard's, St. Andrews, N.B.
1876. ‡Dowie, Mrs. Muir. Golland, by Kinross, N.B.
1884. *Dowling, D. J. Bromley, Kent.
1865. *Dowson, E. Theodore, F.R.M.S. Geldeston, near Beccles, Suffolk.
1881. *Dowson, J. Emerson, M.Inst.C.E. 91 Cheyne-walk, S.W.
1887. ‡Doxey, R. A. Slade House, Levenshulme, Manchester.
1894. ‡Doyne, R. W., F.R.C.S. 28 Beaumont-street, Oxford.
1883. ‡Draper, William. De Grey House, St. Leonard's, York.
1892. *Dreghorn, David, J.P. 188 Nethersdale Drive, Pollokshields, Glasgow.
1868. ‡DRESSER, HENRY E., F.Z.S. 110 Cannon-street, E.C.
1890. ‡Drew, John. 12 Harringay-park, Crouch End, Middlesex, N.
1892. ‡Dreyer, John L. E., M.A., Ph.D., F.R.A.S. The Observatory, Armagh.
1893. §DRUCE, G. CLARIDGE, M.A., F.L.S. (Local Sec. 1894). 118 High-street, Oxford.

Year of Election.

1889. ‡Drummond, Dr. 6 Saville-place, Newcastle-upon-Tyne.
1897. ‡Drynan, Miss. Northwold, Queen's Park, Toronto, Canada.
1901. §Drysdale, John W. W. Bon-Accord Engine Works, London-road, Glasgow.
1892. ‡Du Bois, Dr. H. Mittelstrasse, 39, Berlin.
1856. *DUCIE, The Right. Hon. HENRY JOHN REYNOLDS MORETON, Earl of, F.R.S., F.G.S. 16 Portman-square, W.; and Tortworth Court, Falfield, Gloucestershire.
1870. ‡Duckworth, Henry, F.L.S., F.G.S. Christchurch Vicarage, Chester.
1900. *Duckworth, W. L. H. Jesus College, Cambridge.
1895. *Duddell, William. 47 Hans-place, S.W.
1867. *DUFF, The Right Hon. Sir MOUNTSTUART ELPHINSTONE GRANT-, G.C.S.I., F.R.S., F.R.G.S. (Pres. F, 1867, 1881; Council 1868, 1892–93). 11 Chelsea-embankment, S.W.
1877. ‡Duffey, George F., M.D. 30 Fitzwilliam-place, Dublin.
1875. ‡Duffin, W. E. L'Estrange. Waterford.
1890. ‡Dufton, S. F. Trinity College, Cambridge.
1884. ‡Dugdale, James H. 9 Hyde Park-gardens, W.
1883. ‡Duke, Frederic. Conservative Club, Hastings.
1892. ‡Dulier, Colonel E., C.B. 27 Sloane-gardens, S.W.
1866. *Duncan, James. 9 Mincing-lane, E.C.
1891. *Duncan, John, J.P. 'South Wales Daily News' Office, Cardiff.
1896. ‡Duncanson, Thomas. 16 Deane-road, Liverpool.
1881. ‡Duncombe, The Hon. Cecil, F.G.S. Nawton Grange, York.
1893. *Dunell, George Robert. 33 Spencer-road, Grove Park, Chiswick, Middlesex.
1892. ‡Dunham, Miss Helen Bliss. Messrs. Morton, Rose, & Co., Bartholomew House, E.C.
1896. *DUNKERLEY, S., M.Sc., Professor of Applied Mechanics in the Royal Naval College, Greenwich, S.E.
1865. ‡Dunn, David. Annet House, Skelmorlie, by Greenock, N.B.
1882. ‡Dunn, J. T., M.Sc., F.C.S. Northern Polytechnic Institute, Holloway-road, N.
1883. ‡Dunn, Mrs. J. T. Northern Polytechnic Institute, Holloway-road, N.
1876. ‡Dunnachie, James. 2 West Regent-street, Glasgow.
1884. §Dunnington, Prof. F. P. University of Virginia, Charlottesville, Virginia, U.S.A.
1859. ‡Duns, Rev. John, D.D., F.R.S.E. New College, Edinburgh.
1893. *Dunstan, M. J. R. Sutton Bonington, Loughborough.
1891. ‡Dunstan, Mrs. Sutton Bonington, Loughborough.
1885. *DUNSTAN, WYNDHAM R., M.A., F.R.S., Sec.C.S., Director of the Scientific Department of the Imperial Institute, S.W.
1869. ‡D'Urban, W. S. M., F.L.S. Newport House, near Exeter.
1898. ‡Durrant, R. G. Marlborough College, Wilts.
1895. *Dwerryhouse, Arthur R. 5 Oakfield-terrace, Headingley, Leeds.
1887. ‡*Dyason, John Sanford. Cuthbert Street, W.*
1884. ‡Dyck, Professor Walter. The University, Munich.
1885. *Dyer, Henry, M.A., D.Sc. 8 Highburgh-terrace, Dowanhill, Glasgow.
1869. *Dymond, Edward E. Oaklands, Aspley Guise, Bletchley.
1895. §Dymond, Thomas S., F.C.S. County Technical Laboratory, Chelmsford, Essex.

1868. ‡Eade, Sir Peter, M.D. Upper St. Giles's-street, Norwich.
1895. ‡Earle, Hardman A. 29 Queen Anne's-gate, Westminster, S.W.
1877. ‡Earle, Ven. Archdeacon, M.A. West Alvington, Devon.

Year of Election.

1874. ‡Eason, Charles. 30 Kenilworth-square, Rathgar, Dublin.
1899. §East, W. H. Municipal School of Art, Science, and Technology, Dover.
1871. *EASTON, EDWARD (Pres. G, 1878; Council 1879-81). 11 Delahay-street, Westminster, S.W.
1863. ‡Easton, James. Nest House, near Gateshead, Durham.
1876. ‡Easton, John. Durie House, Abercromby-street, Helensburgh, N.B.
1883. ‡Eastwood, Miss. Littleover Grange, Derby.
1893. *Ebbs, Alfred B. Northumberland-alley, Fenchurch-street, E.C.
1884. ‡Eckersley, W. T. Standish Hall, Wigan, Lancashire.
1861. ‡Ecroyd, William Farrer. Spring Cottage, near Burnley.
1870. *Eddison, John Edwin, M.D., M.R.C.S. The Lodge, Adel, Leeds.
1899. ‡Eddowes, Alfred, M.D. 28 Wimpole-street, W.
*Eddy, James Ray, F.G.S. The Grange, Carleton, Skipton.
1887. ‡Ede, Francis J., F.G.S. Silchar, Cachar, India.
1884. *Edgell, Rev. R. Arnold, M.A., F.C.S. The College House, Leamington.
1887. §EDGEWORTH, F. Y., M.A., D.C.L., F.S.S. (Pres. F, 1889; Council 1879-86, 1891-98), Professor of Political Economy in the University of Oxford. All Souls College, Oxford.
1870. *Edmonds, F. B. 6 Clement's Inn, W.C.
1883. §Edmonds, William. Wiscombe Park, Colyton, Devon.
1888. *Edmunds, Henry. Antron, 71 Upper Tulse-hill, S.W.
1884. *Edmunds, James, M.D. 4 Chichester Terrace, Kemp Town, Brighton.
1883. ‡Edmunds, Lewis, D.Sc., LL.B., F.G.S. 1 Garden-court, Temple, E.C.
1899. §Edwards, E. J. 2 Dafforne Road, Upper Tooting, S.W.
1884. ‡Edwards, W. F. Niles, Michigan, U.S.A.
1887. *Egerton of Tatton, The Right Hon. Lord. Tatton Park, Knutsford.
1901. §Eggar, W. D. Eton College.
1896. ‡Ekkert, Miss Dorothea. 95 Upper Parliament-street, Liverpool.
1876. ‡Elder, Mrs. 6 Claremont-terrace, Glasgow.
1890. §Elford, Percy. St. John's College, Oxford.
1885. *ELGAR, FRANCIS, LL.D., F.R.S., F.R.S.E., M.Inst.C.E. 113 Cannon-street, E.C.
1901. *Elles, Miss Gertrude L. Newnham College, Cambridge.
1883. ‡Ellington, Edward Bayzand, M.Inst.C.E. Palace-chambers, Bridge-street, Westminster, S.W.
1891. ‡Elliott, A. C., D.Sc., Professor of Engineering in University College, Cardiff. 2 Plasturton-avenue, Cardiff.
1883. *ELLIOTT, EDWIN BAILEY, M.A., F.R.S., F.R.A.S., Waynflete Professor of Pure Mathematics in the University of Oxford. 4 Bardwell-road, Oxford.
Elliott, John Fogg. Elvet Hill, Durham.
1886. ‡ELLIOTT, THOMAS HENRY, C.B., F.S.S. Board of Agriculture, 4 Whitehall-place, S.W.
1875. *Ellis, H. D. 12 Gloucester-terrace, Hyde Park, W.
1880. *ELLIS, JOHN HENRY (Local Sec. 1883). Woodhaye, Ivy Bridge, Devon.
1891. §Ellis, Miss M. A. 11 Canterbury-road, Oxford.
1884. ‡Ellis, Professor W. Hodgson, M.A., M.B. 74 St. Alban's-street, Toronto, Canada.
Ellman, Rev. E. B. Berwick Rectory, near Lewes, Sussex.
1887. ‡Elmy, Ben. Congleton, Cheshire.
1862. ‡Elphinstone, Sir H. W., Bart., M.A., F.L.S. 2 Stone-buildings, Lincoln's Inn, W.C.
1899. *Elvery, Miss Amelia. The Cedars, Maison Dieu-road, Dover.

Year of Election.

1897. §Elvery, Mrs. Elizabeth. The Cedars, Maison Dieu-road, Dover.
1883. ‡Elwes, Captain George Robert. Bossington, Bournemouth.
1887. §ELWORTHY, FREDERICK T. Foxdown, Wellington, Somerset.
1870. *ELY, The Right Rev. Lord ALWYNE COMPTON, D.D., Lord Bishop of. The Palace, Ely, Cambridgeshire.
1897. ‡Ely, Robert E. 23 West 44th Street, New York, U.S.A.
1891. ‡Emerton, Wolseley, D.C.L. Banwell Castle, Somerset.
1884. ‡Emery, Albert H. Stamford, Connecticut, U.S.A.
1863. ‡Emery, The Ven. Archdeacon, B.D. Ely, Cambridgeshire.
1894. ‡Emtage, W. T. A. Director of Public Instruction, Mauritius.
1866. ‡Enfield, Richard. Low Pavement, Nottingham.
1884. ‡England, Luther M. Knowlton, Quebec, Canada.
1853. ‡English, E. Wilkins. Yorkshire Banking Company, Lowgate, Hull.
1883. ‡Entwistle, James P. Beachfield, 2 Westclyffe-road, Southport.
1869. *Enys, John Davis. Enys, Penryn, Cornwall.
1894. §Erskine-Murray, James. University College, Nottingham.
1862. *ESSON, WILLIAM, M.A., F.R.S., F.R.A.S., Savilian Professor of Geometry in the University of Oxford. 13 Bradmore-road, Oxford.
1887. *Estcourt, Charles. Hayesleigh, Montague-road, Old Trafford, Manchester.
1887. *Estcourt, P. A., F.C.S., F.I.C. Seymour House, Seymour Street, Manchester.
1869. ‡ETHERIDGE, R., F.R.S., F.R.S.E., F.G.S. (Pres. C, 1882). 14 Carlyle-square, S.W.
1888. ‡Etheridge, Mrs. 14 Carlyle-square, S.W.
1901. §Ettersbank, John. Care of Messrs. Dalgety & Co., 52 Lombard Street, E.C.
1883. ‡Eunson, Henry J., F.G.S., Assoc.M.Inst.C.E. Vizianagram, Madras.
1881. ‡Evans, Alfred, M.A., M.B. Pontypridd.
1889. *EVANS, A. H., M.A. 9 Harvey-road, Cambridge.
1887. *Evans, Mrs. Alfred W. A. Lyndhurst, Upper Chorlton-road, Whalley Range, Manchester.
1870. *EVANS, ARTHUR JOHN, M.A., F.R.S., F.S.A. (Pres. H, 1896). Youlbury, Abingdon.
1865. *EVANS, Rev. CHARLES, M.A. Parkstone, Dorset.
1896. §Evans, Edward, jun. Spital Old Hall, Bromborough, Cheshire.
1891. ‡Evans, Franklen. Llwynarthen, Castleton, Cardiff.
1889. ‡Evans, Henry Jones. Greenhill, Whitchurch, Cardiff.
1883. *Evans, James C. 38 Crescent Road, Birkdale, Southport.
1883. *Evans, Mrs. James C. 38 Crescent Road, Birkdale, Southport.
1861. *EVANS, Sir JOHN, K.C.B., D.C.L., LL.D., D.Sc., F.R.S., F.S.A., F.L.S., F.G.S. (PRESIDENT, 1897; Pres. C, 1878; Pres. H, 1890; Council 1868-74, 1875-82, 1889-96). Nash Mills, Hemel Hempstead.
1897. *Evans, Lady. Nash Mills, Hemel Hempstead.
1898. ‡Evans, Jonathan L. 4 Litfield-place, Clifton, Bristol.
1881. ‡Evans, Lewis. Llanfyrnach, R.S.O., Pembrokeshire.
1885. *Evans, Percy Bagnall. The Spring, Kenilworth.
1865. ‡EVANS, SEBASTIAN, M.A., LL.D. 15 Waterloo-crescent, Dover.
1899. ‡Evans, Mrs. 15 Waterloo-crescent, Dover.
1875. ‡*Evans, Sparke. 3 Apsley-road, Clifton, Bristol.*
1865. *Evans, William. The Spring, Kenilworth.
1891. ‡Evan-Thomas, C., J.P. The Gnoll, Neath, Glamorganshire.
1886. ‡Eve, A. S. Marlborough College, Wilts.
1871. ‡Eve, H. Weston, M.A. 37 Gordon Square, W.C.
1868. *EVERETT, J. D., M.A., D.C.L., F.R.S., F.R.S.E. 11 Leopold Road, Ealing, W.

Year of Election.

1895. ‡Everett, W. H., B.A. University College, Nottingham.
1863. *Everitt, George Allen, F.R.G.S. Knowle Hall, Warwickshire.
1886. ‡Everitt, William E. Finstall Park, Bromsgrove.
1883. ‡Eves, Miss Florence. Uxbridge.
1881. ‡EWART, J. COSSAR, M.D., F.R.S. (Pres. D, 1901), Professor of Natural History in the University of Edinburgh.
1874. ‡EWART, Sir W. QUARTUS, Bart. (Local Sec. 1874; VICE-PRESIDENT 1902). Glenmachan, Belfast.
1876. *EWING, JAMES ALFRED, M.A., B.Sc., F.R.S., F.R.S.E., M.Inst. C.E., Professor of Mechanism and Applied Mechanics in the University of Cambridge. Langdale Lodge, Cambridge.
1883. ‡Ewing, James L. 52 North Bridge, Edinburgh.
1884. *Eyerman, John, F.Z.S. Oakhurst, Easton, Pennsylvania, U.S.A.
1882. ‡Eyre, G. E. Briscoe. Warrens, near Lyndhurst, Hants.
Eyton, Charles. Hendred House, Abingdon.

1890. ‡FABER, EDMUND BECKETT. Straylea, Harrogate.
1896. ‡Fairbrother, Thomas. 46 Lethbridge-road, Southport.
1901. §Fairgrieve, M. McCallum. New College, Eastbourne.
1865. *FAIRLEY, THOMAS, F.R.S.E., F.C.S. 8 Newton-grove, Leeds.
1896. ‡Falk, Herman John, M.A. Thorshill, West Kirby, Liverpool.
1883. ‡*Fallon, Rev. W. S.* *9 St. James's-square, Cheltenham.*
1898. §Faraday, Miss Ethel R., M.A. Ramsay Lodge, Levenshulme, near Manchester.
1877. §FARADAY, F. J., F.L.S., F.S.S. (Local Sec. 1887). College-chambers, 17 Brazennose-street, Manchester.
1891. ‡*Fards, G.* *Penarth.*
1892. *FARMER, J. BRETLAND, M.A., F.R.S., F.L.S., Professor of Botany, Royal College of Science, Exhibition-road, S.W.
1886. ‡Farncombe, Joseph, J.P. Saltwood, Spencer-road, Eastbourne.
1897. *Farnworth, Ernest. Broadlands, Goldthorn Hill, Wolverhampton.
1897. *Farnworth, Mrs. Ernest. Broadlands, Goldthorn Hill, Wolverhampton.
1883. ‡Farnworth, Walter. 86 Preston New-road, Blackburn.
1883. ‡Farnworth, William. 86 Preston New-road, Blackburn.
1885. ‡Farquhar, Admiral. Carlogie, Aberdeen.
1886. ‡FARQUHARSON, Colonel Sir J., K.C.B., R.E. Corrachee, Tarland, Aberdeen.
1859. ‡Farquharson, Robert F. O. Netherton Meigle, N.B.
1885. *Farquharson, Mrs. R. F. O. Netherton Meigle, N.B.
1866. *FARRAR, The Very Rev. FREDERIC WILLIAM, D.D., F.R.S. The Deanery, Canterbury.
1883. ‡Farrell, John Arthur. Moynalty, Kells, North Ireland.
1897. ‡Farthing, Rev. J. C., M.A. The Rectory, Woodstock, Ontario, Canada.
1869. *Faulding, Joseph. Boxley House, Tenterden, Kent.
1883. ‡Faulding, Mrs. Boxley House, Tenterden, Kent.
1887. §Faulkner, John. 13 Great Ducie-street, Strangeways, Manchester.
1890. *Fawcett, F. B. University College, Bristol.
1900. §FAWCETT, J. E., J.P. (Local Sec. 1900). Low Royd, Apperley Bridge, Bradford.
1901. *Fearnsides, W. G. Addingford Hill, Horbury, Yorkshire.
1886. ‡Felkin, Robert W., M.D., F.R.G.S. 6 Crouch Hall-road, N.
Fell, John B. Spark's Bridge, Ulverstone, Lancashire.
1900. *Fennell, W. John. Kilcoroon, Stockman's Lane, Belfast.
1883. ‡Fenwick, E. H. 29 Harley-street, W.

Year of Election.

1890. ‡Fenwick, T. Chapel Allerton, Leeds.
1901. §Fergus, Freeland, M.D. 22 Blythswood Square, Glasgow.
1876. ‡Ferguson, Alexander A. 11 Grosvenor-terrace, Glasgow.
1883. ‡Ferguson, Mrs. A. A. 11 Grosvenor-terrace, Glasgow.
1902. §FERGUSON, GODFREY W. (LOCAL SECRETARY, 1902). Cluaw, Donegall Park, Belfast.
1871. *FERGUSON, JOHN, M.A., LL.D., F.R.S.E., F.S.A., F.C.S., Professor of Chemistry in the University of Glasgow.
1896. *Ferguson, John. Colombo, Ceylon.
1867. ‡Ferguson, Robert M., LL.D., Ph.D., F.R.S.E. 5 Learmouth-terrace, Edinburgh.
1901. §Ferguson, R. W. 125 Church Street, Edgware Road, N.W.
1883. ‡Fernald, H. P. Clarence House, Promenade, Cheltenham.
1883. *Fernie, John. Box No. 2, Hutchinson, Kansas, U.S.A.
1862. ‡FERRERS, Rev. NORMAN MACLEOD, D.D., F.R.S. (Local Sec. 1862). Caius College Lodge, Cambridge.
1873. ‡FERRIER, DAVID, M.A., M.D., LL.D., F.R.S., Professor of Neuro-Pathology in King's College, London. 34 Cavendish-square, W.
1892. ‡Ferrier, Robert M., B.Sc. Professor of Engineering, University College, Bristol.
1897. ‡Ferrier, W. F. Geological Survey, Ottawa, Canada.
1897. †Fessenden, Reginald A., Professor of Electrical Engineering, University, Alleghany, Pennsylvania, U.S.A.
1882. §Fewings, James, B.A., B.Sc. King Edward VI. Grammar School, Southampton.
1887. ‡Fiddes, Thomas, M.D. Penwood, Urmston, near Manchester.
1875. ‡Fiddes, Walter. Clapton Villa, Tyndall's Park, Clifton, Bristol.
1868. ‡Field, Edward. Norwich.
1897. ‡Field, George Wilton, Ph.D. Experimental Station, Kingston, Rhode Island, U.S.A.
1886. ‡Field, H. C. 4 Carpenter-road, Edgbaston, Birmingham.
1882. ‡Filliter, Freeland. St. Martin's House, Wareham, Dorset.
1883. *Finch, Gerard B., M.A. 1 St. Peter's-terrace, Cambridge.
1878. *Findlater, Sir William. 22 Fitzwilliam-square, Dublin.
1884. ‡Finlay, Samuel. Montreal, Canada.
1887. ‡Finnemore, Rev. J., M.A., Ph.D., F.G.S. 88 Upper Hanover-street, Sheffield.
1881. †Firth, Colonel Sir Charles. Heckmondwike.
1895. §Fish, Frederick J. Spursholt, Park-road, Ipswich.
1891. ‡Fisher, Major H. O. The Highlands, Llandough, near Cardiff.
1884. *Fisher, L. C. Galveston, Texas, U.S.A.
1869. ‡FISHER, Rev. OSMOND, M.A., F.G.S. Harlton Rectory, near Cambridge.
1875. *Fisher, W. W., M.A., F.C.S. 5 St. Margaret's-road, Oxford.
1858. ‡Fishwick, Henry. Carr-hill, Rochdale.
1887. *Fison, Alfred H., D.Sc. 25 Blenheim-gardens, Willesden Green, N.W.
1885. ‡Fison, E. Herbert. Stoke House, Ipswich.
1871. *FISON, FREDERICK W., M.A., M.P., F.C.S. Greenholme, Burley-in-Wharfedale, near Leeds.
1871. ‡FITCH, Sir J. G., M.A., LL.D. (Council, 1871–75). Athenæum Club, S.W.
1883. ‡Fitch, Rev. J. J. Ivyholme, Southport.
1878. ‡Fitzgerald, C. E., M.D. 27 Upper Merrion-street, Dublin.
1885. *FITZGERALD, Professor MAURICE, B.A. (LOCAL SECRETARY, 1902). 32 Eglantine-avenue, Belfast.
1894. ‡Fitzmaurice, M., M.Inst.C.E. London County Council, Spring Gardens, S.W.

Year of Election.

1888. *Fitzpatrick, Rev. Thomas C. Christ's College, Cambridge.
1897. ‡Flavelle, J. W. 565 Jarvis-street, Toronto, Canada.
1881. ‡Fleming, Rev. Canon J., B.D. St. Michael's Vicarage, Ebury-square, S.W.
1876. ‡Fleming, James Brown. Beaconsfield, Kelvinside, Glasgow.
1876. ‡Fleming, Sir Sandford, K.C.M.G., F.G.S. Ottawa, Canada.
1867. ‡Fletcher, Alfred E., F.C.S. Delmore, Caterham, Surrey.
1870. ‡Fletcher, B. Edgington. Norwich.
1890. ‡Fletcher, B. Morley. 7 Victoria-street, S.W.
1892. ‡Fletcher, George, F.G.S. 60 Connaught-avenue, Plymouth.
1888. *Fletcher, Lazarus, M.A., F.R.S., F.G.S., F.C.S. (Pres. C, 1894), Keeper of Minerals, British Museum (Natural History), Cromwell-road, S.W. 36 Woodville-road, Ealing, W.
1901. §Flett, J. S. Edinburgh.
1889. ‡Flower, Lady. 26 Stanhope-gardens, S.W.
1877. *Floyer, Ernest A. Green Hill, Worcester.
1890. *Flux, A. W., M.A., Professor of Political Economy in the University, Montreal.
1891. ‡Foldvary, William. Museum Ring, 10, Buda Pesth.
1880. ‡Foote, R. Bruce, F.G.S. Care of Messrs. H. S. King & Co., 65 Cornhill, E.C.
1873. *Forbes, George, M.A., F.R.S., F.R.S.E., M.Inst.C.E. 34 Great George-street, S.W.
1883. ‡Forbes, Henry O., LL.D., F.Z.S., Director of Museums for the Corporation of Liverpool. The Museum, Liverpool.
1897. ‡Forbes, J., K.C. Hazeldean, Putney-hill, S.W.
1885. ‡Forbes, The Right Hon. Lord. CastleForbes, Aberdeenshire.
1890. ‡Ford, J. Rawlinson (Local Sec. 1890). Quarry Dene, Weetwood-lane, Leeds.
1875. *Fordham, H. George. Odsey, Ashwell, Baldock, Herts.
1894. ‡Forrest, Frederick. Beechwood, Castle Hill, Hastings.
1887. ‡Forrest, The Right Hon. Sir John, G.C.M.G., F.R.G.S., F.G.S. Perth, Western Australia.
1883. ‡Forsyth, A. R., M.A., D.Sc., F.R.S. (Pres. A, 1897), Sadlerian Professor of Pure Mathematics in the University of Cambridge. Trinity College, Cambridge.
1900. ‡Forsyth, D. Central Higher Grade School, Leeds.
1884. ‡Fort, George H. Lakefield, Ontario, Canada.
1877. ‡Fortescue, The Right Hon. the Earl. Castle Hill, North Devon.
1896. ‡Forwood, Sir William B., J.P. Ramleh, Blundellsands, Liverpool.
1875. ‡Foster, A. Le Neve. 51 Cadogan-square, S.W.
1865. ‡Foster, Sir B. Walter, M.D., M.P. 16 Temple-row, Birmingham.
1865. *Foster, Clement Le Neve, B.A., D.Sc., F.R.S., F.G.S., Professor of Mining in the Royal College of Science, London.
1883. ‡Foster, Mrs. C. Le Neve.
1857. *Foster, George Carey, B.A., F.R.S., V.P.C.S. (General Treasurer, 1898– ; Pres. A, 1877; Council 1871–76, 1877–82). Ladywalk, Rickmansworth.
1896. ‡Foster, Miss Harriet. Cambridge Training College, Wollaston-road, Cambridge.
1877. §Foster, Joseph B. 4 Cambridge-street, Plymouth.
1859. *Foster, Sir Michael, K.C.B., M.P., M.A., M.D., LL.D., D.C.L., Sec.R.S., F.L.S. (President, 1899; Gen. Sec. 1872–76; Pres. I, 1897; Council, 1871–72), Professor of Physiology in the University of Cambridge. Great Shelford, Cambridge.
1901. §Foster, T. Gregory, Ph.D. University College, W.C., and Clifton, Northwood, Middlesex.

Year of Election.

1896. ‡Fowkes, F. Hawkshead, Ambleside.
1866. ‡Fowler, George, M.Inst.C.E., F.G.S. Basford Hall, near Nottingham.
1868. ‡Fowler, G. G. Gunton Hall, Lowestoft, Suffolk.
1892. ‡Fowler, Miss Jessie A. 4 & 5 Imperial-buildings, Ludgate-circus, E.C.
1901. §Fowlis, William. 45 John Street, Glasgow.
1883. *Fox, Charles. The Chestnuts, Warlingham on the Hill, Surrey.
1883. §Fox, Sir Charles Douglas, M.Inst.C.E. (Pres. G, 1896). 28 Victoria-street, Westminster, S.W.
1896. ‡Fox, Henry J. Bank's Dale, Bromborough, near Liverpool.
1883. ‡Fox, Howard, F.G.S. Rosehill, Falmouth.
1847. *Fox, Joseph Hoyland. The Clive, Wellington, Somerset.
1900. *Fox, Thomas. Pyles Thorne House, Wellington, Somerset.
1881. *Foxwell, Herbert S., M.A., F.S.S. (Council 1894–97), Professor of Political Economy in University College, London. St. John's College, Cambridge.
1889. ‡Frain, Joseph, M.D. Grosvenor-place, Jesmond, Newcastle-upon-Tyne.
Francis, William, Ph.D., F.L.S., F.G.S., F.R.A.S. Red Lion-court, Fleet-street, E.C.; and Manor House, Richmond, Surrey.
1887. *Frankland, Percy F., Ph.D., B.Sc., F.R.S. (Pres. B, 1901). Professor of Chemistry in the University, Birmingham.
1894. §Franklin, Mrs. E. L. 50 Porchester-terrace, W.
1895. §Fraser, Alexander. 63 Church-street, Inverness.
1882. *Fraser, Alexander, M.B., Professor of Anatomy in the Royal College of Surgeons, Dublin.
1885. ‡Fraser, Angus, M.A., M.D., F.C.S. (Local Sec. 1885). 232 Union-street, Aberdeen.
1865. *Fraser, John, M.A., M.D., F.G.S. Chapel Ash, Wolverhampton.
1871. ‡Fraser, Thomas R., M.D., F.R.S., F.R.S.E., Professor of Materia Medica and Clinical Medicine in the University of Edinburgh. 13 Drumsheugh-gardens, Edinburgh.
1871. ‡Frazer, Evan L. R. Brunswick-terrace, Spring Bank, Hull.
1884. *Frazer, Persifor, M.A., D.Sc. (Univ. de France). Room 1042, Drexel Building, Philadelphia, U.S.A.
1884. *Fream, W., LL.D., B.Sc., F.L.S., F.G.S., F.S.S. The Vinery, Downton, Salisbury.
1877. §Freeman, Francis Ford. Abbotsfield, Tavistock, South Devon.
1884. *Fremantle, The Hon. Sir C. W., K.C.B. (Pres. F, 1892; Council 1897–). 4 Lower Sloane-street, S.W.
1869. ‡Frere, Rev. William Edward. The Rectory, Bitton, near Bristol.
1886. ‡Freshfield, Douglas W., F.R.G.S. 1 Airlie-gardens, Campden Hill, W.
1901. §Frew, William, Ph.D. 11 Hillhead Street, Glasgow.
1887. ‡Fries, Harold H., Ph.D. 92 Reade-street, New York, U.S.A.
1887. †*Froehlich, The Cavaliere. Grosvenor Terrace, Withington, Manchester.*
1892. *Frost, Edmund, M.B. Chesterfield, Meads, Eastbourne.
1882. §Frost, Edward P., J.P. West Wratting Hall, Cambridgeshire.
1887. *Frost, Robert, B.Sc. 53 Victoria-road, W.
1899. ‡Fry, Edward W. Cannon-street, Dover.
1898. ‡Fry, The Right Hon. Sir Edward, D.C.L., LL.D., F.R.S., F.S.A. Failand House, Failand, near Bristol.
1898. ‡Fry, Francis J. Leigh Woods, Clifton, Bristol.
1875. *Fry, Joseph Storrs. 17 Upper Belgrave-road, Clifton, Bristol.
1898. ‡Fryer, Alfred C., Ph.D. 13 Eaton-crescent, Clifton, Bristol.
1884. ‡Fryer, Joseph, J.P. Smelt House, Howden-le-Wear, Co. Durham.

Year of Election.

1895. ‡FULLARTON, Dr. J. H. Fishery Board for Scotland, George-street, Edinburgh.
1872. *Fuller, Rev. A. 7 Sydenham-hill, Sydenham, S.E.
1859. ‡FULLER, FREDERICK, M.A. (Local Sec. 1859). 9 Palace-road, Surbiton.
1869. ‡FULLER, G., M.Inst.C.E. (Local Sec. 1874). 71 Lexham-gardens, Kensington, W.
1884. ‡Fuller, William, M.B. Oswestry.
1891. ‡Fulton, Andrew. 23 Park-place, Cardiff.

1887. ‡Gaddum, G. H. Adria House, Toy-lane, Withington, Manchester.
1863. *Gainsford, W. D. Skendleby Hall, Spilsby.
1896. ‡Gair, H. W. 21 Water-street, Liverpool.
1850. ‡GAIRDNER, Sir W. T., K.C.B., M.D., LL.D., F.R.S. 32 George Square, Edinburgh.
1876. ‡Gale, James M. 23 Miller-street, Glasgow.
1885. *Gallaway, Alexander. Dirgarve, Aberfeldy, N.B.
1861. ‡Galloway, Charles John. Knott Mill Iron Works, Manchester.
1889. ‡Galloway, Walter. Eighton Banks, Gateshead.
1875. ‡GALLOWAY, W. Cardiff.
1887. *Galloway, W. J., M.P. The Cottage, Seymour-grove, Old Trafford, Manchester.
1899. §Galton, Lady Douglas. Himbleton Manor, Droitwich.
1860. *GALTON, FRANCIS, M.A., D.C.L., D.Sc., F.R.S., F.G.S., F.R.G.S. (GEN. SEC. 1863-68; Pres. E, 1862, 1872; Pres. H, 1885; Council 1860-63). 42 Rutland-gate, Knightsbridge, S.W.
1869. ‡GALTON, JOHN C., M.A., F.L.S. New University Club, St. James's-street, S.W.
1870. §Gamble, Lieut.-Colonel Sir D., Bart., C.B. St. Helens, Lancashire.
1889. ‡Gamble, David. Ratonagh, Colwyn Bay.
1870. ‡Gamble, J. C. St. Helens, Lancashire.
1888. *GAMBLE, J. SYKES, C.I.E., F.R.S., M.A., F.L.S. Highfield, East Liss, Hants.
1877. ‡Gamble, William. St. Helens, Lancashire.
1868. ‡GAMGEE, ARTHUR, M.D., F.R.S. (Pres. D, 1882; Council 1888-90). 5 Avenue du Kursaal, Montreux, Switzerland.
1899. *Garcke, E. Sunnyside, Bedford Park, Chiswick, W.
1898. §Garde, Rev. C. L. Skenfrith Vicarage, near Monmouth.
1900. §Gardiner, J. Stanley, M.A. Dunstall, Newton Road, Cambridge.
1887. ‡GARDINER, WALTER, M.A., F.R.S., F.L.S. 45 Hills-road, Cambridge.
1882. *Gardner, H. Dent, F.R.G.S. Fairmead, 46 The Goffs, Eastbourne.
1896. ‡Gardner, James. The Groves, Grassendale, Liverpool.
1894. ‡Gardner, J. Addyman. 5 Bath-place, Oxford.
1882. ‡GARDNER, JOHN STARKIE. 29 Albert Embankment, S.E.
1884. ‡Garman, Samuel. Cambridge, Massachusetts, U.S.A.
1887. *Garnett, Jeremiah. The Grange, Bromley Cross, near Bolton, Lancashire.
1882. ‡Garnett, William, D.C.L. London County Council, Spring-gardens, S.W.
1873. ‡Garnham, John. Hazelwood, Crescent-road, St. John's, Brockley, Kent, S.E.
1883. ‡GARSON, J. G., M.D. 14 Stratford Place, W.
1894. *GARSTANG, WALTER, M.A., F.Z.S. Marine Biological Laboratory, Plymouth.
1874. *Garstin, John Ribton, M.A., LL.B., M.R.I.A., F.S.A. Bragans-town, *Castlebellingham, Ireland.*

Year of Election.

1882. ‡Garton, William. Woolston, Southampton.
1892. ‡Garvie, James. Bolton's Park, Potter's Bar.
1889. ‡GARWOOD, Professor E. J., B.A., F.G.S. University College, Gower Street, W.C.
1870. ‡Gaskell, Holbrook. Woolton Wood, Liverpool.
1870. *Gaskell, Holbrook, jun. Bridge House, Sefton Park, Liverpool.
1896. *GASKELL, WALTER HOLBROOK, M.A., M.D., LL.D., F.R.S. (Pres. I, 1896; Council 1898–1901). The Uplands, Great Shelford, near Cambridge.
1896. §Gatehouse, Charles. Westwood, Noctorum, Birkenhead.
1862. *Gatty, Charles Henry, M.A., LL.D., F.R.S.E., F.L.S., F.G.S. Felbridge Place, East Grinstead, Sussex.
1890. ‡Gaunt, Sir Edwin. Carlton Lodge, Leeds.
1875. ‡Gavey, J. Hollydale, Hampton Wick, Middlesex.
1892. ‡Geddes, George H. 8 Douglas-crescent, Edinburgh.
1871. ‡Geddes, John. 9 Melville-crescent, Edinburgh.
1883. ‡Geddes, John. 33 Portland-street, Southport.
1885. ‡GEDDES, Professor PATRICK. Ramsay-garden, Edinburgh.
1887. ‡Gee, W. W. Haldane. Owens College, Manchester.
1867. ‡GEIKIE, Sir ARCHIBALD, LL.D., D.Sc., F.R.S., F.R.S.E., F.G.S. (PRESIDENT, 1892; Pres. C, 1867, 1871, 1899; Council 1888–91). 10 Chester-terrace, Regent's-park, N.W.
1871. ‡GEIKIE, JAMES, LL.D., D.C.L., F.R.S., F.R.S.E., F.G.S. (Pres. C, 1889; E, 1892), Murchison Professor of Geology and Mineralogy in the University of Edinburgh. Kilmorie, Colinton-road, Edinburgh.
1898. §Gemmill, James F., M.A., M.B. 16 Dargavel-avenue, Dumbreck, Glasgow.
1882. *GENESE, R. W., M.A., Professor of Mathematics in University College, Aberystwyth.
1875. *George, Rev. Hereford Brooke, M.A., F.R.G.S. Holywell Lodge, Oxford.
1885. ‡Gerard, Robert. Blair-Devenick, Cults, Aberdeen.
1884. *Gerrans, Henry T., M.A. 20 St. John-street, Oxford.
1884. ‡Gibb, Charles. Abbotsford, Quebec, Canada.
1865. ‡Gibbins, William. Battery Works, Digbeth, Birmingham.
1874. ‡Gibson, The Right Hon. Edward, K.C. 23 Fitzwilliam-square, Dublin.
1892. ‡Gibson, Francis Maitland. Care of Professor Gibson, 20 George-square, Edinburgh.
1901. §Gibson, Professor George A., M.A. 103 Renfrew Street, Glasgow.
1876. *Gibson, George Alexander, M.D., D.Sc., F.R.S.E. 3 Drumsheugh Gardens, Edinburgh.
1896. †GIBSON, HARVEY, M.A., Professor of Botany, University College, Liverpool.
1892. ‡Gibson, James. 20 George Square, Edinburgh.
1884. ‡Gibson, Rev. James J. 183 Spadina-avenue, Toronto, Canada.
1889. *Gibson, T. G. Lesbury House, Lesbury, R.S.O., Northumberland.
1893. ‡Gibson, Walcot, F.G.S. 28 Jermyn-street, S.W.
1887. *GIFFEN, Sir ROBERT, K.C.B., LL.D., F.R.S., V.P.S.S. (Pres. F, 1887, 1901). Athenæum Club, S.W., and 40 Brunswick Road, Hove, Brighton.
1898. *Gifford, J. William. Chard.
1884. ‡Gilbert E. E. 245 St. Antoine-street, Montreal, Canada.
1883. §Gilbert, Lady. Harpenden, near St. Albans.
1857. ‡Gilbert, J. T., M.R.I.A. Villa Nova, Blackrock, Dublin.
1884. *Gilbert, Philip H. 63 Tupper-street, Montreal, Canada.
1895. ‡Gilchrist, J. D. F. Carvenon Anstruther, Scotland.

Year of
Election.

1896. *GILCHRIST, PERCY C., F.R.S., M.Inst.C.E. Frognal Bank, Finchley-road, Hampstead, N.W.
1878. ‡Giles, Oliver. Brynteg, The Crescent, Bromsgrove.
1871. *GILL, Sir DAVID, K.C.B., LL.D., F.R.S., F.R.A.S. Royal Observatory, Cape Town.
1884. ‡Gillman, Henry. 130 Lafayette-avenue, Detroit, Michigan, U.S.A.
1896. ‡Gilmour, H. B. Underlea, Aigburth, Liverpool.
1892. *Gilmour, Matthew A. B., F.Z.S. Saffronhall House, Windmill-road, Hamilton, N.B.
1867. ‡Gilroy, Robert. Craigie, by Dundee.
1893. *Gimingham, Edward. Cranbourne Mansions, Cranbourne Street, W.C.
1900. §Ginsburg, Benedict W., M.A., LL.D. Royal Statistical Society, 9 Adelphi Terrace, W.C.
1867. ‡GINSBURG, Rev. C. D., D.C.L., LL.D. Holmlea, Virginia Water Station, Chertsey.
1884. ‡Girdwood, Dr. G. P. 28 Beaver Hall-terrace, Montreal, Canada.
1886. *Gisborne, Hartley, M.Can.S.C.E. Caragana Lodge, Ladysmith, Vancouver Island, Canada.
1850. *Gladstone, George, F.R.G.S. 34 Denmark-villas, Hove, Brighton.
1849. *GLADSTONE, JOHN HALL, Ph.D., D.Sc., F.R.S., V.P.C.S. (Pres. B, 1872, 1883; Council 1860–65). 17 Pembridge-square, W.
1883. *Gladstone, Miss. 17 Pembridge-square, W.
1861. *GLAISHER, JAMES, F.R.S., F.R.A.S. The Shola, Heathfield-road, South Croydon.
1871. *GLAISHER, J. W. L., M.A., D.Sc., F.R.S., F.R.A.S. (Pres. A, 1890; Council 1878–86). Trinity College, Cambridge.
1901. §Glaister, Professor John, M.D., F.R.S.E. 18 Woodside Place, Glasgow.
1897. †Glashan, J. C., LL.D. Ottawa, Canada.
1883. ‡Glasson, L. T. 2 Roper-street, Penrith.
1881. *GLAZEBROOK, R. T., M.A., F.R.S., Director of the National Physical Laboratory (Pres. A, 1893; Council 1890–94). Bushy House, Teddington, Middlesex.
1881. *Gleadow, Frederic. 38 Ladbroke-grove, W.
1859. ‡Glennie, J. S. Stuart, M.A. Verandah Cottage, Haslemere, Surrey.
1874. ‡Glover, George T. Corby, Hoylake.
Glover, Thomas. 124 Manchester-road, Southport.
1870. ‡Glynn, Thomas R., M.D. 62 Rodney-street, Liverpool.
1872. ‡GODDARD, RICHARD. 16 Booth-street, Bradford, Yorkshire.
1899. §Godfrey, Ingram F. Brook House, Ash, Dover.
1886. ‡Godlee, Arthur. The Lea, Harborne, Birmingham.
1887. ‡Godlee, Francis. 8 Minshall-street, Manchester.
1878. *Godlee, J. Lister. 3 Clarence-terrace, Regent's Park, N.W.
1880. ‡GODMAN, F. DU CANE, D.C.L., F.R.S., F.L.S., F.G.S. 10 Chandos-street, Cavendish-square, W.
1883. ‡Godson, Dr. Alfred. Cheadle, Cheshire.
1852. ‡Godwin, John. Wood House, Rostrevor, Belfast.
1879. ‡GODWIN-AUSTEN, Lieut.-Colonel H. H., F.R.S., F.G.S., F.R.G.S. F.Z.S. (Pres. E, 1883). Shalford House, Guildford.
1876. ‡Goff, Bruce, M.D. Bothwell, Lanarkshire.
1898. ‡Goldney, F. B. Goodnestone Park, Dover.
1881. ‡GOLDSCHMIDT, EDWARD, J.P. Nottingham.
1886. ‡GOLDSMID, Major-General Sir F. J., K.C.S.I., C.B., F.R.G.S. (Pres. E, 1886). Godfrey House, Hollingbourne.
1899. ‡GOMME, G. L., F.S.A. 24 Dorset-square, N.W.
1890. *GONNER, E. C. K., M.A. (Pres. F, 1897), Professor of Political Economy in University College, Liverpool.

Year of Election.

1884. ‡Good, Charles E. 102 St. François Xavier-street, Montreal, Canada.
1852. ‡Goodbody, Jonathan. Clare, King's County, Ireland.
1878. ‡Goodbody, Jonathan, jun. 50 Dame-street, Dublin.
1884. ‡Goodbody, Robert. Fairy Hill, Blackrock, Co. Dublin.
1885. ‡GOODMAN, J. D., J.P. Peachfield, Edgbaston, Birmingham.
1884. *Goodridge, Richard E. W. Lupton, Michigan, U.S.A.
1884. ‡Goodwin, Professor W. L. Queen's University, Kingston, Ontario, Canada.
1885. †Gordon, Rev. Cosmo, D.D., F.R.A.S., F.G.S. Chetwynd Rectory, Newport, Salop.
1871. *Gordon, Joseph Gordon, F.C.S. Queen Anne's Mansions, Westminster, S.W.
1893. ‡Gordon, Mrs. M. M., D.Sc. 1 Rubislaw-terrace, Aberdeen.
1884. *Gordon, Robert, M.Inst.C.E., F.R.G.S. Fairview, Dartmouth, Devon.
1899. §Gordon, T. Kirkman. 15 Hampden Street, Nottingham.
1885. ‡Gordon, Rev. William. Braemar, N.B.
1865. ‡GORE, GEORGE, LL.D., F.R.S. 20 Easy-row, Birmingham.
1901. §GORST, Right Hon. Sir JOHN E., M.A., K.C., M.P., F.R.S. (Pres. L, 1901). Queen Anne's Mansions, S.W.
1875. *GOTCH, FRANCIS, M.A., B.Sc., F.R.S. (Council, 1901–). Professor of Physiology in the University of Oxford. The Lawn, Banbury-road, Oxford.
1873. ‡Gott, Charles, M.Inst.C.E. Parkfield-road, Manningham, Bradford, Yorkshire.
1849. ‡Gough, The Hon. Frederick. Perry Hall, Birmingham.
1881. ‡Gough, Rev. Thomas, B.Sc. King Edward's School, Retford.
1894. ‡Gould, G. M., M.D. 119 South 17th-street, Philadelphia, U.S.A.
1888. †Gouraud, Colonel. Gwydyr Mansions, Hove, Sussex.
1901. §GOURLAY, ROBERT. Glasgow.
1867. ‡Gourley, Henry (Engineer). Dundee.
1901. §Gow, Leonard. Hayston, Kelvinside, Glasgow.
1876. ‡Gow, Robert. Cairndowan, Dowanhill Gardens, Glasgow.
1883. §Gow, Mrs. Cairndowan, Dowanhill Gardens, Glasgow.
1873. §Goyder, Dr. D. Marley House, 88 Great Horton-road, Bradford, Yorkshire.
1886. ‡Grabham, Michael C., M.D. Madeira.
1901. §Graham, Robert. 155 Nithsdale Road, Pollokshields, Glasgow.
1875. ‡GRAHAME, JAMES (Local Sec. 1876). 12 St. Vincent-street, Glasgow.
1892. ‡Grange, C. Ernest. 57 Berners-street, Ipswich.
1893. ‡Granger, Professor F. S., M.A., D.Litt. 2 Cranmer-street, Nottingham.
1896. ‡Grant, Sir James, K.C.M.G. Ottawa, Canada.
1892. †Grant, W. B. 10 Ann-street, Edinburgh.
1864. ‡Grantham, Richard F., M.Inst.C.E., F.G.S. Northumberland-chambers, Northumberland-avenue, W.C.
1881. ‡Gray, Alan, LL.B. Minster-yard, York.
1899. ‡Gray, Albert Alexander. 16 Berkeley-terrace, Glasgow.
1890. ‡GRAY, ANDREW, M.A., LL.D., F.R.S., F.R.S.E., Professor of Natural Philosophy in the University of Glasgow.
1899. ‡Gray, Charles. 11 Portland-place, W.
1864. *Gray, Rev. Canon Charles. West Retford Rectory, Retford.
1876. ‡Gray, Dr. Newton-terrace, Glasgow.
1881. ‡Gray, Edwin, LL.B. Minster-yard, York.
1893. ‡Gray, J. C., General Secretary of the Co-operative Union, Limited, Long Millgate, Manchester.

Year of Election.

1892. *Gray, James Hunter, M.A., B.Sc. 141 Hopton Road, Streatham, S.W.
1870. ‡Gray, J. Macfarlane. 4 Ladbroke-crescent, W.
1892. §Gray, John, B.Sc. 351 Coldharbour-lane, Brixton, S.W.
1887. ‡Gray, Joseph W., F.G.S. St. Elmo, Leckhampton-road, Cheltenham.
1887. ‡Gray, M. H., F.G.S. Lessness Park, Abbey Wood, Kent.
1886. *Gray, Robert Kaye. Lessness Park, Abbey Wood, Kent.
1901. §Gray, R. W. 7 Orme Court, Bayswater, W.
1881. ‡Gray, Thomas, Professor of Engineering in the Rane Technical Institute, Terre Haute, Indiana, U.S.A.
1873. ‡Gray, William, M.R.I.A. Glenburn Park, Belfast.
*GRAY, Colonel WILLIAM. Farley Hall, near Reading.
1883. ‡Gray, William Lewis. Westmoor Hall, Brimsdown, Middlesex.
1883. ‡Gray, Mrs. W. L. Westmoor Hall, Brimsdown, Middlesex.
1886. ‡Greaney, Rev. William. Bishop's House, Bath-street, Birmingham.
1866. §Greaves, Charles Augustus, M.B., LL.B. 84 Friar-gate, Derby.
1893. *Greaves, Mrs. Elizabeth. Station-street, Nottingham.
1869. ‡Greaves, William. Station-street, Nottingham.
1872. ‡Greaves, William. 33 Marlborough-place, N.W.
1872. *Grece, Clair J., LL.D. 146 Station Road, Redhill, Surrey.
1901. §Green, Dr. Edridge. Hendon, N.W.
1888. §GREEN, J. REYNOLDS, M.A., D.Sc., F.R.S., F.L.S., Professor of Botany to the Pharmaceutical Society of Great Britain. 61A St. Andrews Street, Cambridge.
1887. ‡*Greene, Friese.* 162 *Sloane-street, S.W.*
1882. ‡GREENHILL, A. G., M.A., F.R.S., Professor of Mathematics in the Royal Artillery College, Woolwich. 10 New Inn, W.C.
1881. ‡Greenhough, Edward. Matlock Bath, Derbyshire.
1884. ‡Greenish, Thomas, F.C.S. 20 New-street, Dorset-square, N.W.
1898. *GREENLY, EDWARD. Achnashean, near Bangor, North Wales.
1884. ‡Greenshields, E. B. Montreal, Canada.
1884. ‡Greenshields, Samuel. Montreal, Canada.
1887. ‡Greenwell, G. C., jun. Beechfield, Poynton, Cheshire.
1863. ‡Greenwell, G. E. Poynton, Cheshire.
1890. ‡Greenwood, Arthur. Cavendish-road, Leeds.
1875. ‡Greenwood, F., M.B. Brampton, Chesterfield.
1877. ‡*Greenwood, Holmes.* 78 *King Street, Accrington.*
1887. ‡Greenwood, W. H., M.Inst.C.E. Adderley Park Rolling Mills, Birmingham.
1887. *Greg, Arthur. Eagley, near Bolton, Lancashire.
1861. *GREG, ROBERT PHILIPS, F.G.S., F.R.A.S. Coles Park, Buntingford, Herts.
1894. *GREGORY, Professor J. WALTER, D.Sc., F.R.S., F.G.S. Melbourne, Australia.
1896. *Gregory, R. A. 19 Westover Road, Wandsworth Common, S.W
1883. ‡Gregson, G. E. Ribble View, Preston.
1881. ‡Gregson, William, F.G.S. Baldersby, S.O., Yorkshire.
1859. ‡GRIERSON, THOMAS BOYLE, M.D. Thornhill, Dumfriesshire.
1878. ‡Griffin, Robert, M.A., LL.D. Trinity College, Dublin.
1836. Griffin, S. F. Albion Tin Works, York-road, N.
1894. *Griffith, C. L. T., Assoc.M.Inst.C.E. Portland Cement Co., Demopolis, Alabama, U.S.A.
1850. *GRIFFITH, G. (ASSISTANT GENERAL SECRETARY, 1862–78, 1890– ; Sec. 1881; Local Sec. 1860). College-road, Harrow, Middlesex.
1884. ‡GRIFFITHS, E. H., M.A., F.R.S. University College, Cardiff.
1884. ‡Griffiths, Mrs. University College, Cardiff.
1891. ‡Griffiths, P. Rhys, B.Sc., M.B. 71 Newport-road, Cardiff.

Year of Election.

1847. ‡Griffiths, Thomas. The Elms, Harborne-road, Edgbaston, Birmingham.
1870. ‡Grimsdale, T. F., M.D. Hoylake, Liverpool.
1888. *Grimshaw, James Walter, M.Inst.C.E. Australian Club, Sydney, New South Wales.
1884. †Grinnell, Frederick. Providence, Rhode Island, U.S.A.
1894. ‡Groom, Professor P., M.A., F.L.S. Hollywood, Egham, Surrey.
1894. §Groom, T. T., D.Sc. The Poplars, Hereford.
1896. ‡Grossmann, Dr. Karl. 70 Rodney-street, Liverpool.
1892. ‡Grove, Mrs. Lilly, F.R.G.S. Mason College, Birmingham.
1891. ‡Grover, Henry Llewellin. Clydach Court, Pontypridd.
1863. *Groves, Thomas B. Broadley, Westerhall-road, Weymouth.
1869. ‡Grubb, Sir Howard, F.R.S., F.R.A.S. 51 Kenilworth-square, Rathgar, Dublin.
1897. ‡Grünbaum, A. S., M.A., M.D. 45 Ladbroke Grove, W.
1897. ‡Grünbaum, O. F. F., B.A., D.Sc. 45 Ladbroke Grove, W.
1886. †Grundy, John. 17 Private-road, Mapperley, Nottingham.
1891. ‡Grylls, W. London and Provincial Bank, Cardiff.
1887. ‡Guillemard, F. H. H. Eltham, Kent.
Guinness, Henry. 17 College-green, Dublin.
1842. Guinness, Richard Seymour. 17 College-green, Dublin.
1891. ‡Gunn, Sir John. Llandaff House, Llandaff.
1877. ‡Gunn, William, F.G.S. Office of the Geological Survey of Scotland, Sheriff's Court House, Edinburgh.
1866. ‡Günther, Albert C. L. G., M.A., M.D., Ph.D., F.R.S., Pres.L.S., F.Z.S. (Pres. D, 1880). 22 Lichfield-road, Kew, Surrey.
1894. ‡Günther, R. T. Magdalen College, Oxford.
1880. §Guppy, John J. Ivy-place, High-street, Swansea.
1883. ‡Guthrie, Malcolm. Prince's-road, Liverpool.
1896. ‡Guthrie, Tom, B.Sc. Yorkshire College, Leeds.
1876. ‡Gwyther, R. F., M.A. Owens College and 33 Heaton Road, Withington, Manchester.

1884. ‡Haanel, E., Ph.D. Cobourg, Ontario, Canada.
1884. ‡Hadden, Captain C. F., R.A. Woolwich.
1881. *Haddon, Alfred Cort, M.A., F.R.S., F.Z.S. Inisfail, Hills-road, Cambridge.
1842. Hadfield, George. Victoria Park, Manchester.
1888. *Hadfield, R. A., M.Inst.C.E. The Grove, Endcliffe Vale-road, Sheffield.
1892. ‡Haigh, E., M.A. Longton, Staffordshire.
1870. ‡Haigh, George. 27 Highfield South, Rockferry, Cheshire.
1879. ‡Hake, H. Wilson, Ph.D., F.C.S. Queenwood College, Hants.
1899. §Hall, A. D. South-Eastern Agricultural College, Wye, Kent.
1879. *Hall, Ebenezer. Abbeydale Park, near Sheffield.
1881. ‡Hall, Frederick Thomas, F.R.A.S. 15 Gray's Inn-square, W.C.
1854. *Hall, Hugh Fergie, F.G.S. Cowley House, Headington Hill, Oxford.
1898. §Hall, J. P. The 'Tribune,' New York, U.S.A.
1899. §Hall, John, M.D. National Bank of Scotland, 37 Nicholas-lane, E.C.
1885. §Hall, Samuel, F.I.C., F.C.S. 19 Aberdeen-park, Highbury, N.
1900. ‡Hall, T. Farmer, F.R.G.S. 39 Gloucester Square, Hyde Park, W.
1896. ‡Hall, Thomas B. Larch Wood, Rockferry, Cheshire.
1884. ‡Hall, Thomas Proctor. School of Practical Science, Toronto, Canada.
1896. ‡Hall-Dare, Mrs. Caroline. 13 Great Cumberland-place, W.

Year of Election.

1891. *Hallett, George. Cranford, Victoria-road, Penarth, Glamorganshire.
1891. §Hallett, J. H., M.Inst.C.E. Maindy Lodge, Cardiff.
1873. *HALLETT, T. G. P., M.A. Claverton Lodge, Bath.
1888. §HALLIBURTON, W. D., M.D., F.R.S. (Council 1897–), Professor of Physiology in King's College, London. Church Cottage, 17 Marylebone-road, W.
Halsall, Edward. 4 Somerset-street, Kingsdown, Bristol.
1858. *Hambly, Charles Hambly Burbridge. F.G.S. Fairley, Weston, Bath.
1883. *Hamel, Egbert D. de. Middleton Hall, Tamworth.
1885. ‡Hamilton, David James. 41 Queen's-road, Aberdeen.
1902. §§HAMILTON, Rev. T., D.D. (VICE-PRESIDENT, 1902). Belfast.
1881. *Hammond, Robert. 64 Victoria-street, Westminster, S.W.
1899. *Hanbury, Daniel. La Mortola, Ventimiglia, Italy.
1892. ‡Hanbury, Thomas, F.L.S. La Mortola, Ventimiglia, Italy.
1878. ‡Hance, Edward M., LL.B. Municipal Offices, Liverpool.
1875. ‡Hancock, C. F., M.A. 125 Queen's-gate, S.W.
1897. †HANCOCK, HARRIS. University of Chicago, U.S.A.
1861. ‡Hancock, Walter. 10 Upper Chadwell-street, Pentonville, E.C.
1890. ‡Hankin, Ernest Hanbury. St. John's College, Cambridge.
1884. ‡Hannaford, E. P., M.Inst.C.E. 2573 St. Catherine-street, Montreal.
1894. §Hannah, Robert, F.G.S. 82 Addison-road, W.
1886. §Hansford, Charles, J.P. Englefield House, Dorchester.
1859. *HARCOURT, A. G. VERNON, M.A., D.C.L., LL.D., F.R.S., V.P.C.S. (GEN. SEC. 1883–97; Pres. B, 1875; Council 1881–83). Cowley Grange, Oxford.
1890. *HARCOURT, L. F. VERNON, M.A., M.Inst.C.E. (Pres. G, 1895; Council 1895–1901). 6 Queen Anne's-gate, S.W.
1900. §Harcourt, Hon. R., K.C., Minister of Education for the Province of Ontario, Toronto, Canada.
1886. *Hardcastle, Basil W., F.S.S. 12 Gainsborough-gardens, Hampstead, N.W.
1892. *HARDEN, ARTHUR, Ph.D., M.Sc. Jenner Institute of Preventive Medicine, Chelsea Gardens, Grosvenor Road, S.W.
1877. ‡Harding, Stephen. Bower Ashton, Clifton, Bristol.
1869. ‡Harding, William D. Islington Lodge, King's Lynn, Norfolk.
1894. ‡Hardman, S. C. 225 Lord-street, Southport.
1894. ‡Hare, A. T., M.A. Neston Lodge, East Twickenham, Middlesex.
1894. ‡Hare, Mrs. Neston Lodge, East Twickenham, Middlesex.
1898. ‡Harford, W. H. Oldown House, Almondsbury.
1858. ‡Hargrave, James. Burley, near Leeds.
1883. ‡Hargreaves, Miss H. M. 69 Alexandra-road, Southport.
1883. ‡Hargreaves, Thomas. 69 Alexandra-road, Southport.
1890. ‡Hargrove, Rev. Charles. 10 De Grey-terrace, Leeds.
1881. ‡Hargrove, William Wallace. St. Mary's, Bootham, York.
1890. *HARKER, ALFRED, M.A., F.G.S. St. John's College, Cambridge.
1896. ‡Harker, Dr. John Allen. Springfield House, Stockport.
1887. ‡Harker, T. H. Brook House, Fallowfield, Manchester.
1878. *Harkness, H. W., M.D. California Academy of Sciences, San Francisco, California, U.S.A.
1871. ‡Harkness, William, F.C.S. 1 St. Mary's-road, Canonbury, N.
1875. *Harland, Rev. Albert Augustus, M.A., F.G.S., F.L.S., F.S.A. The Vicarage, Harefield, Middlesex.
1877. *Harland, Henry Seaton. 8 Arundel-terrace, Brighton.
1883. *Harley, Miss Clara. Rosslyn, Westbourne-road, Forest Hill, S.E.
1883. *Harley, Harold. 14 Chapel-street, Bedford-row, W.C.
1862. *HARLEY, Rev. ROBERT, M.A., F.R.S., F.R.A.S. Rosslyn, Westbourne-road, Forest Hill, S.E.

Year of Election.

1899. ‡Harman, Dr. N. Bishop. St. John's College, Cambridge.
1868. *HARMER, F. W., F.G.S. Oakland House, Cringleford, Norwich.
1881. *HARMER, SIDNEY F., M.A., D.Sc., F.R.S. King's College, Cambridge.
1872. ‡Harpley, Rev. William, M.A. Clayhanger Rectory, Tiverton.
1884. ‡Harrington, B. J., B.A., Ph.D., F.G.S., Professor of Chemistry and Mineralogy in McGill University, Montreal. University-street, Montreal, Canada.
1888. ‡Harris, C. T. 4 Kilburn Priory, N.W.
1842. *Harris, G. W., M.Inst.C.E. Millicent, South Australia.
1889. §HARRIS, H. GRAHAM, M.Inst.C.E. 5 Great George-street, Westminster, S.W.
1898. ‡Harrison, A. J., M.D. Failand Lodge, Guthrie-road, Clifton, Bristol.
1888. ‡Harrison, Charles. 20 Lennox-gardens, S.W.
1860. ‡Harrison, Rev. Francis, M.A. North Wraxall, Chippenham.
1889. ‡Harrison, J. C. Oxford House, Castle-road, Scarborough.
1858. *HARRISON, J. PARK, M.A. 22 Connaught-street, Hyde Park, W.
1892. ‡HARRISON, JOHN (Local Sec. 1892). Rockville, Napier-road, Edinburgh.
1870. ‡HARRISON, REGINALD, F.R.C.S. (Local Sec. 1870). 6 Lower Berkeley-street, Portman-square, W.
1853. ‡Harrison, Robert. 36 George-street, Hull.
1892. ‡Harrison, Rev. S. N. Ramsey, Isle of Man.
1895. ‡Harrison, Thomas. 48 High-street, Ipswich.
1901. *Harrison, W. E. 43 Mostyn Road, Handsworth, Staffordshire.
1886. ‡Harrison, W. Jerome, F.G.S. Board School, Icknield-street, Birmingham.
1885. ‡Hart, Col. C. J. Highfield Gate, Edgbaston, Birmingham.
1876. *Hart, Thomas. Brooklands, Blackburn.
1875. ‡Hart, W. E. Kilderry, near Londonderry.
1893. *HARTLAND, E. SIDNEY, F.S.A. Highgarth, Gloucester.
1897. ‡Hartley, E. G. S. Wheaton Astley Hall, Stafford.
1871. *HARTLEY, WALTER NOEL, F.R.S., F.R.S.E., F.C.S., Professor of Chemistry in the Royal College of Science, Dublin. 36 Waterloo-road, Dublin.
1896. ‡Hartley, W. P., J.P. Aintree, Liverpool.
1886. *HARTOG, Professor M. M., D.Sc. Queen's College, Cork.
1887. ‡HARTOG, P. J., B.Sc. Owens College, Manchester.
1897. ‡Harvey, Arthur. Rosedale, Toronto, Canada.
1898. ‡Harvey, Eddie. 10 The Paragon, Clifton, Bristol.
1885. §Harvie-Brown, J. A. Dunipace, Larbert, N.B.
1862. *Harwood, John. Woodside Mills, Bolton-le-Moors.
1884. ‡Haslam, Rev. George, M.A. Trinity College, Toronto, Canada.
1893. §Haslam, Lewis. 44 Evelyn-gardens, S.W.
1875. *HASTINGS, G. W. Elm Lodge, Dartford Heath, Bexley, Kent.
1889. ‡Hatch, F. H., Ph.D., F.G.S. 28 Jermyn-street, S.W.
1893. ‡Hatton, John L. S. People's Palace, Mile End-road, E.
1887. *Hawkins, William. Earlston House, Broughton Park, Manchester.
1872. *Hawkshaw, Henry Paul. 58 Jermyn-street, St. James's, S.W.
1864. *‡HAWKSHAW, JOHN CLARKE, M.A., M.Inst.C.E., F.G.S. (Council 1881–87). 22 Down-street, W., and 33 Great George-street, S.W.
1897. §Hawksley, Charles. 60 Porchester-terrace, W.
1884. *Haworth, Abraham. Hilston House, Altrincham.
1889. ‡Haworth, George C. Ordsal, Salford.
1887. *Haworth, Jesse. Woodside, Bowdon, Cheshire.

Year of Election.

1887. ‡Haworth, S. E. Warsley-road, Swinton, Manchester.
1886. ‡*Haworth, Rev. T. J. Albert Cottage, Saltley, Birmingham.*
1890. ‡Hawtin, J. N. Sturdie House, Roundhay-road, Leeds.
1861. *HAY, Admiral the Right Hon. Sir JOHN C. D. Bart., K.C.B., D.C.L., F.R.S. 108 St. George's-square, S.W.
1885. *HAYCRAFT, JOHN BERRY, M.D., B.Sc., F.R.S.E., Professor of Physiology, University College, Cardiff.
1891. ‡Hayde, Rev. J. St. Peter's, Cardiff.
1900. §Hayden, H. H. Geological Survey, Calcutta, India.
1894. ‡Hayes, Edward Harold. 5 Rawlinson-road, Oxford.
1896. ‡Hayes, Rev. F. C. The Rectory, Raheny, Dublin.
1896. ‡Hayes, William. Fernyhurst, Rathgar, Dublin.
1873. *Hayes, Rev. William A., M.A. Dromore, Co. Down, Ireland.
1898. ‡Hayman, C. A. Kingston Villa, Richmond Hill, Clifton, Bristol.
1858. *HAYWARD, R. B., M.A., F.R.S. Ashcombe, Shanklin, Isle of Wight.
1896. *Haywood, A. G. Rearsby, Merrilocks-road, Blundellsands.
1879. *Hazelhurst, George S. The Grange, Rockferry.
1883. ‡Headley, Frederick Halcombe. Manor House, Petersham, S.W.
1883. ‡Headley, Mrs. Marian. Manor House, Petersham, S.W.
1883. ‡Headley, Rev. Tanfield George. Manor House, Petersham, S.W.
1883. ‡Heape, Charles. Tovrak, Oxton, Cheshire.
1883. ‡Heape, Joseph R. Glebe House, Rochdale.
1882. *Heape, Walter, M.A. Heyroun, Chaucer-road, Cambridge.
1877. ‡Hearder, Henry Pollington. Westwell-street, Plymouth.
1877. ‡Hearder, William Keep. 195 Union-street, Plymouth.
1883. ‡Heath, Dr. 46 Hoghton-street, Southport.
1898. *Heath, Arthur J. 10 Grove Road, Redland, Bristol.
1898. ‡HEATH, R. S., M.A., D.Sc. The University, Birmingham.
1884. ‡Heath, Thomas, B.A. Royal Observatory, Edinburgh.
1883. ‡Heaton, Charles. Marlborough House, Hesketh Park, Southport.
1892. *HEATON, WILLIAM H., M.A. (Local Sec. 1893), Professor of Physics in University College, Nottingham.
1889. *Heaviside, Arthur West. 7 Grafton-road, Whitley, Newcastle-upon-Tyne.
1884. §Heaviside, Rev. George, B.A., F.R.G.S., F.R.Hist.S. 7 Grosvenor-street, Coventry.
1888. *Heawood, Edward, M.A. 3 Underhill-road, Lordship-lane, S.E.
1888. *Heawood, Percy J., Lecturer in Mathematics at Durham University. 41 Old Elvet, Durham.
1855. ‡HECTOR, Sir JAMES, K.C.M.G., M.D., F.R.S., F.G.S., Director of the Geological Survey of New Zealand. Wellington, New Zealand.
1887. *HEDGES, KILLINGWORTH, M.Inst.C.E. Wootton Lodge, 39 Streatham-hill, S.W.
1881. *HELE-SHAW, H. S., LL.D., F.R.S., M.Inst.C.E., Professor of Engineering in University College, Liverpool. 27 Ullet-road, Liverpool.
1901. §Heller, W. M., B.Sc. 18 Belgrave Square, Monkstown, Co. Dublin.
1887. §Hembry, Frederick William, F.R.M.S. Langford, Sidcup, Kent.
1897. §Hemming, G. W., K.C. 2 Earl's Court-square, S.W.
1899. §Hemsalech, G. A. 42 Museum Street, W.C.
1867. ‡Henderson, Alexander. Dundee.
1873. *Henderson, A. L. Westmoor Hall, Brimsdown, Middlesex.
1883. ‡Henderson, Mrs. A. L. Westmoor Hall, Brimsdown, Middlesex.
1901. §Henderson, Rev. Andrew, LL.D. Castle Head, Paisley.
1891. *HENDERSON, G. G., D.Sc., M.A., F.C.S., F.I.C., Professor of Chemistry in the Glasgow and West of Scotland Technical College. 204 George-street, Glasgow.

Year of
Election.

1892. ‡Henderson, John. 3 St. Catherine-place, Grange, Edinburgh.
1885. ‡Henderson, Sir William. Devanha House, Aberdeen.
1880. *Henderson, Rear-Admiral W. H., R.N. United Service Club, Pall Mall, S.W.
1896. ‡Henderson, W. Saville, B.Sc. Beech Hill, Fairfield, Liverpool.
1856. ‡HENNESSY, HENRY G., F.R.S., M.R.I.A. Palazzo Ferruzzi, Zattere, Venice.
1873. *HENRICI, OLAUS M. F. E., Ph.D., F.R.S. (Pres. A, 1883; Council, 1883-89), Professor of Mechanics and Mathematics in the City and Guilds of London Institute, Central Institution, Exhibition-road, S.W. 34 Clarendon-road, Notting Hill, W.
Henry, Franklin. Portland-street, Manchester.
Henry, Mitchell. Stratheden House, Hyde Park, W.
1892. ‡HEPBURN, DAVID, M.D., F.R.S.E. The University, Edinburgh.
1855. *Hepburn, J. Gotch, LL.B., F.C.S. Oakfield Cottage, Dartford Heath, Kent.
1855. ‡Hepburn, Robert. 9 Portland-place, W.
1890. ‡Hepper, J. 43 Cardigan-road, Headingley, Leeds.
1890. ‡Hepworth, Joseph. 25 Wellington-street, Leeds.
1892. *HERBERTSON, ANDREW J., Ph.D., F.R.S.E., F.R.G.S. 25 Norham Road, Oxford.
1887. *HERDMAN, WILLIAM A., D.Sc., F.R.S., F.R.S.E., F.L.S. (Pres. D, 1895; Council, 1894-1900; Local Sec. 1896), Professor of Natural History in University College, Liverpool. Croxteth Lodge, Sefton Park, Liverpool.
1893. *Herdman, Mrs. Croxteth Lodge, Sefton Park, Liverpool.
1891. ‡Hern, S. South Cliff, Marine Parade, Penarth.
1871. *HERSCHEL, ALEXANDER S., M.A., D.C.L., F.R.S., F.R.A.S., Honorary Professor of Physics and Experimental Philosophy in the University of Durham. Observatory House, Slough, Bucks.
1874. §HERSCHEL, Colonel JOHN, R.E., F.R.S., F.R.A.S. Observatory House, Slough, Bucks.
1900. *Herschel, J. C. W. Littlemore, Oxford.
1900. ‡Herschel, Sir W. J., Bart. Littlemore, Oxford.
1895. §Hesketh, James. Scarisbrick Avenue-buildings, 107 Lord-street, Southport.
1894. ‡HEWETSON, G. H. (Local Sec. 1896). 39 Henley-road, Ipswich.
1894. ‡Hewins, W. A. S., M.A., F.S.S. Professor of Political Economy in King's College, Strand, W.C.
1896. §Hewitt, David Basil. Oakleigh, Northwich, Cheshire.
1893. ‡Hewitt, Thomas P. Eccleston Park, Prescot, Lancashire.
1883. ‡Hewson, Thomas. Junior Constitutional Club, Piccadilly, W.
1882. ‡HEYCOCK, CHARLES T., M.A., F.R.S. King's College, Cambridge.
1883. §Heyes, Rev. John Frederick, M.A., F.R.G.S. 90 Arkwright Street, Bolton.
1866. *Heymann, Albert. West Bridgford, Nottinghamshire.
1897. ‡Heys, Thomas. 130 King-street West, Toronto, Canada.
1901. *Heys, Z. John. Stonehouse, Barrhead, N.B.
1879. ‡Heywood, Sir A. Percival, Bart. Duffield Bank, Derby.
1886. ‡HEYWOOD, HENRY, J.P., F.C.S. Witla Court, near Cardiff.
1887. ‡Heywood, Robert. Mayfield, Victoria Park, Manchester.
1888. ‡Hichens, James Harvey, M.A., F.G.S. The School House, Wolverhampton.
1898. §Hicks, Henry B. 44 Pembroke-road, Clifton, Bristol.
1877. §HICKS, Professor W. M., M.A., D.Sc., F.R.S., (Pres. A, 1895), Principal of University College, Dunheved, Endcliffe Crescent, Sheffield.

Year of Election.

1886. ‡Hicks, Mrs. W. M. Dunheved, Endcliffe-crescent, Sheffield.
1884. ‡Hickson, Joseph. 272 Mountain-street, Montreal, Canada.
1887. *Hickson, Sydney J., M.A., D.Sc., F.R.S., Professor of Zoology in Owens College, Manchester.
1864. *Hiern, W. P., M.A. The Castle, Barnstaple.
1891. ‡Higgs, Henry, LL.B., F.S.S. (Pres. F, 1899). H.M. Treasury, Whitehall, S.W.
1894. ‡Hill, Rev. A. Du Boulay. East Bridgford Rectory, Nottingham.
1885. *Hill, Alexander, M.A., M.D. *Downing College, Cambridge.*
1898. ‡Hill, Charles. Clevedon.
*Hill, Rev. Canon Edward, M.A., F.G.S. Sheering Rectory, Harlow.
1881. *Hill, Rev. Edwin, M.A. The Rectory, Cockfield, Bury St. Edmunds.
1887. ‡Hill, G. H., M.Inst.C.E., F.G.S. Albert-chambers, Albert-square, Manchester.
1884. ‡Hill, Rev. James Edgar, M.A., B.D. 2488 St. Catherine-street, Montreal, Canada.
1886. ‡Hill, M. J. M., M.A., D.Sc., F.R.S., Professor of Pure Mathematics in University College, W.C.
1885. *Hill, Sidney. Langford House, Langford, Bristol.
1898. *Hill, Thomas Sidney. Langford House, Langford, Bristol.
1888. ‡Hill, William. Hitchin, Herts.
1876. ‡Hill, William H. Barlanark, Shettleston, N.B.
1885. *Hillhouse, William, M.A., F.L.S., Professor of Botany in Mason Science College. 16 Duchess-road, Edgbaston, Birmingham.
1886. §Hillier, Rev. E. J. Cardington Vicarage, near Bedford.
1863. ‡Hills, F. C. Chemical Works, Deptford, Kent, S.E.
1887. ‡Hilton, Edwin. Oak Bank, Fallowfield, Manchester.
1870. ‡Hinde, G. J., Ph.D., F.R.S., F.G.S. Ivythorn, Avondale-road, South Croydon, Surrey.
1883. *Hindle, James Henry. 8 Cobham-street, Accrington.
1888. *Hindmarsh, William Thomas, F.L.S. Alnbank, Alnwick.
1898. §Hinds, Henry. 57 Queen-street, Ramsgate.
1886. ‡Hingley, Sir Benjamin, Bart. Hatherton Lodge, Cradley, Worcestershire.
1881. ‡Hingston, J. T. Clifton, York.
1884. ‡Hingston, Sir William Hales, M.D., D.C.L. 37 Union-avenue, Montreal, Canada.
1900. §Hinks, Arthur R., M.A. 10 Huntingdon Road, Cambridge.
1884. ‡Hirschfilder, C. A. Toronto, Canada.
1899. §Hobday, Henry. Hazelwood, Crabble Hill, Dover.
1879. ‡Hobkirk, Charles P., F.L.S. The Headlands, Scotland-lane, Horsforth, near Leeds.
1887. *Hobson, Bernard, B.Sc., F.G.S. Thornton, Parkfield Road, Didsbury.
1883. ‡Hobson, Mrs. Carey. 5 Beaumont-crescent, West Kensington, W.
1883. ‡Hobson, Rev. E. W. 55 Albert-road, Southport.
1883. ‡*Hocking, Rev. Silas K. 21 Scarisbrick New-road, Southport.*
1877. ‡Hodge, Rev. John Mackey, M.A. 38 Tavistock-place, Plymouth.
1876. ‡Hodges, Frederick W. Queen's College, Belfast.
1863. *Hodgkin, Thomas, B.A., D.C.L. Benwell Dene, Newcastle-upon-Tyne.
1887. *Hodgkinson, Alexander, M.B., B.Sc., Lecturer on Laryngology at Owens College, Manchester. 18 St. John-street, Manchester.
1896. ‡Hodgkinson, Arnold. 16 Albert-road, Southport.
1880. §Hodgkinson, W. R. Eaton, Ph.D., F.R.S.E., F.G.S., Professor of Chemistry and Physics in the Royal Artillery College, Woolwich. 18 Glencoe-road, Blackheath, S.E.

Year of Election.

1884. ‡Hodgson, Jonathan. Montreal, Canada.
1863. ‡Hodgson, R. W. 7 Sandhill, Newcastle-upon-Tyne.
1898. ‡Hodgson, T. V. Municipal Museum and Art Gallery, Plymouth.
1896. ‡Hodgson, Dr. Wm., J.P. Helensville, Crewe.
1894. ‡Hogg, A. F., M.A. 13 Victoria-road, Darlington.
1894. ‡Holah, Ernest. 5 Crown-court, Cheapside, E.C.
1883. ‡*Holden, Edward. Laurel Mount, Shipley, Yorkshire.*
1883. ‡Holden, James. 12 Park-avenue, Southport.
1883. ‡Holden, John J. 23 Duke-street, Southport.
1884. ‡Holden, Mrs. Mary E. Dunham Ladies' College, Quebec, Canada.
1887. *Holder, Henry William, M.A. Sheet, near Petersfield.
1896. ‡Holder, Thomas. 2 Tithebarn-street, Liverpool.
1900. §HOLDICH, Col. Sir THOMAS H., R.E., K.C.I.E. Army and Navy Club, 36 Pall Mall, S.W.
1887. *Holdsworth, C. J. Sunnyside, Wilmslow, Cheshire.
1891. ‡Holgate, Benj., F.G.S. The Briars, North Park Avenue, Roundhay, Leeds.
1879. ‡Holland, Calvert Bernard. Hazel Villa, Thicket-road, Anerley, S.E.
1896. §Holland, Mrs. Lowfields House, Hooton.
1898. ‡Holland, Thomas H., F.G.S. Geological Survey Office, Calcutta.
1889. ‡Holländer, Bernard, M.D. King's College, Strand, W.C.
1886. ‡Holliday, J. R. 101 Harborne-road, Birmingham.
1883. ‡Hollingsworth, Dr. T. S. Elford Lodge, Spring Grove, Isleworth
1883. *Holmes, Mrs. Basil. 5 Freeland-road, Ealing, Middlesex, W.
1866. *Holmes, Charles. 24 Aberdare-gardens, West Hampstead, N.W.
1892. ‡Holmes, Matthew. Netherby, Lenzie, Scotland.
1882. *HOLMES, THOMAS VINCENT, F.G.S. 28 Croom's-hill, Greenwich, S.E.
1896. ‡Holt, William Henry. 11 Ashville-road, Birkenhead.
1897. ‡Holterman, R. F. Brantford, Ontario, Canada.
1891. *Hood, Archibald, M.Inst.C.E. Sherwood, Cardiff.
1875. *Hood, John. Chesterton, Cirencester.
1847. ‡HOOKER, Sir JOSEPH DALTON, G.C.S.I., C.B., M.D., D.C.L., LL.D., F.R.S., F.L.S., F.G.S., F.R.G.S. (PRESIDENT, 1868; Pres. E, 1881; Council 1866-67). The Camp, Sunningdale, Berkshire.
1892. ‡HOOKER, REGINALD H., M.A. 3 Gray's Inn-place, W.C.
1865. *Hooper, John P. Deepdene, Rutford-road, Streatham, S.W.
1877. *Hooper, Rev. Samuel F., M.A. Lydlinch Rectory, Sturminster Newton, Dorset.
1856. ‡Hooton, Jonathan. 116 Great Ducie-street, Manchester.
1901. *Hopkinson, Bertram, M.A. Holmwood, Wimbledon.
1884. *HOPKINSON, CHARLES (Local Sec. 1887). The Limes, Didsbury, near Manchester.
1882. *Hopkinson, Edward, M.A., D.Sc. Oakleigh, Timperley, Cheshire.
1871. *HOPKINSON, JOHN, F.L.S., F.G.S., F.R.Met.Soc. 84 New Bond Street, W.; and Westwood, St. Albans.
1858. ‡Hopkinson, Joseph, jun. Britannia Works, Huddersfield.
1891. ‡Horder, T. Garrett. 10 Windsor-place, Cardiff.
1898. *Hornby, R., M.A. King William's College, Isle of Man.
1885. ‡HORNE, JOHN, F.R.S., F.R.S.E., F.G.S. (Pres. C 1901). Geological Survey Office, Sheriff Court-buildings, Edinburgh.
1875. *Horniman, F. J., M.P., F.R.G.S., F.L.S. Falmouth House, 20 Hyde Park-terrace, W.
1884. *Horsfall, Richard. Stoodley House, Halifax.
1887. ‡Horsfall, T. C. Swanscoe Park, near Macclesfield.
1893. *HORSLEY, Professor VICTOR A. H., B.Sc., F.R.S., F.R.C.S. (Council 1893–98.) 25 Cavendish-square, W.
1884. *Hotblack, G. S. Brundall, Norwich.

Year of Election.

1899. ‡Hotblack, J. T. 45 Newmarket-road, Norwich.
1859. ‡Hough, Joseph, M.A., F.R.A.S. Codsall Wood, Wolverhampton.
1896. *Hough, S. S. Royal Observatory, Cape Town.
1886. ‡Houghton, F. T. S., M.A., F.G.S. 188 Hagley-road, Edgbaston, Birmingham.
1887. ‡Houldsworth, Sir W. H., Bart., M.P. Norbury Booths, Knutsford.
1896. ‡Hoult, J. South Castle-street, Liverpool.
1884. ‡Houston, William. Legislative Library, Toronto, Canada.
1883. *Hovenden, Frederick, F.L.S., F.G.S. Glenlea, Thurlow Park-road, West Dulwich, Surrey, S.E.
1893. ‡Howard, F. T., M.A., F.G.S. University College, Cardiff.
1883. ‡Howard, James Fielden, M.D., M.R.C.S. Sandycroft, Shaw.
1887. *Howard, S. S. 58 Albemarle-road, Beckenham, Kent.
1899. §Howard-Hayward, H. Harbledown, 120 Queen's-road, Richmond, Surrey.
1901. §Howarth, E. Public Museum, Weston Park, Sheffield.
1886. ‡Howatt, David. 3 Birmingham-road, Dudley.
1876. ‡Howatt, James. 146 Buchanan-street, Glasgow.
1899. ‡Howden, Ian D. C. 6 Cambridge-terrace, Dover.
1889. ‡Howden, Robert, M.B., Professor of Anatomy in the University of Durham College of Medicine, Newcastle-upon-Tyne.
1857. ‡Howell, Henry H., F.G.S. 13 Cobden Crescent, Edinburgh.
1898. ‡Howell, J. H. 104 Pembroke-road, Clifton, Bristol.
1891. ‡Howell, Rev. William Charles, M.A. Holy Trinity Parsonage, High Cross, Tottenham, Middlesex.
1886. §Howes, G. B., LL.D., F.R.S., F.L.S. Professor of Zoology in the Royal College of Science, South Kensington, S.W.
1901. §Howie, Robert Y. 41 Mill Road, Paisley.
1884. ‡Howland, Edward P., M.D. 211 41½-street, Washington, U.S.A.
1884. ‡Howland, Oliver Aiken. Toronto, Canada.
1865. *Howlett, Rev. Frederick, F.R.A.S. 7 Prince's Buildings, Clifton, Bristol.
1863. ‡Howorth, Sir H. H., K.C.I.E., M.P., D.C.L., F.R.S., F.S.A. 30 Collingham-place, Cromwell-road, S.W.
1883. ‡Howorth, John, J.P. Springbank, Burnley, Lancashire.
1883. ‡Hoyle, James. Blackburn.
1887. §Hoyle, William E., M.A. Owens College, Manchester.
1888. ‡Hudd, Alfred E., F.S.A. 94 Pembroke-road, Clifton, Bristol.
1898. §Hudleston, W. H., M.A., F.R.S., F.G.S. (Pres. C, 1898). 8 Stanhope-gardens, S.W.
1888. ‡Hudson, C. T., M.A., LL.D., F.R.S. Hillside, Clarence Road, Shanklin, Isle of Wight.
1867. *Hudson, William H. H., M.A., Professor of Mathematics in King's College, London. 15 Altenberg-gardens, Clapham Common, S.W.
1858. *Huggins, Sir William, K.C.B., D.C.L. Oxon., LL.D. Camb., Pres.R.S., F.R.A.S. (President, 1891; Council, 1868–74, 1876–84). 90 Upper Tulse-hill, S.W.
1887. ‡Hughes, E. G. 4 Roman-place, Higher Broughton, Manchester.
1883. ‡Hughes, Miss E. P. Cambridge Teachers' College, Cambridge.
1871. *Hughes, George Pringle, J.P. Middleton Hall, Wooler, Northumberland.
1887. ‡Hughes, John Taylor. Thorleymoor, Ashley-road, Altrincham.
1896. ‡Hughes, John W. New Heys, Allerton, Liverpool.
1891. ‡Hughes, Thomas, F.C.S. 31 Loudoun-square, Cardiff.
1868. §Hughes, T. M'K., M.A., F.R.S., F.G.S., Woodwardian Professor of Geology in the University of Cambridge. 18 Hills-road, Cambridge.

Year of Election.

1891. ‡Hughes, Rev. W. Hawker. Jesus College, Oxford.
1867. §HULL, EDWARD, M.A., LL.D., F.R.S., F.G.S. (Pres. C, 1874). 20 Arundel-gardens, Notting Hill, W.
1897. ‡Hume, J. G., M.A., Ph.D. 650 Church-street, Toronto, Canada.
1901. §Hume, John. 63 Bridgegate, Irvine.
1887. *HUMMEL, Professor J. J. 152 Woodsley-road, Leeds.
1890 ‡Humphrey, Frank W. 63 Prince's-gate, S.W.
1878. ‡Humphreys, H. Castle-square, Carnarvon.
1880. ‡Humphreys, Noel A., F.S.S. Ravenhurst, Hook, Kingston-on-Thames.
1877. *HUNT, ARTHUR ROOPE, M.A., F.G.S. Southwood, Torquay.
1891. *Hunt, Cecil Arthur. Southwood, Torquay.
1886. ‡Hunt, Charles. The Gas Works, Windsor-street, Birmingham.
1891. ‡Hunt, D. de Vere, M.D. Westbourne-crescent, Sophia-gardens, Cardiff.
1875. *Hunt, William. North Cote, Westbury-on-Trym, Bristol.
1881. ‡Hunter, F. W. Newbottle, Fence Houses, Co. Durham.
1889. ‡Hunter, Mrs. F. W. Newbottle, Fence Houses, Co. Durham.
1901. §Hunter, G. M., Assoc.M.Inst.C.E. Honda, Colombia, S. America.
1881. ‡Hunter, Rev. John. University-gardens, Glasgow.
1884. *Hunter, Michael. Greystones, Sheffield.
1901. *Hunter, William. Evirallan, Stirling.
1879. ‡HUNTINGTON, A. K., F.C.S., Professor of Metallurgy in King's College, W.C.
1885. ‡Huntly, The Most Hon. the Marquess of. Aboyne Castle, Aberdeenshire.
1863. ‡Huntsman, Benjamin. West Retford Hall, Retford.
1898. ‡Hurle, J. Cooke. Southfield House, Brislington, Bristol.
1869. ‡Hurst, George. Bedford.
1882. *Hurst, Walter, B.Sc. Kirkgate, Tadcaster, Yorkshire.
1861. *Hurst, William John. Drumaness, Ballynahinch, Co. Down, Ireland.
1887. ‡*Husband, W. E.* *56 Bury New-road, Manchester.*
1882. ‡*Hussey, Major E. R., R.E.* *24 Waterloo-place, Southampton.*
1894. *Hutchinson, A. Pembroke College, Cambridge.
Hutton, Crompton. Harescombe Grange, Stroud, Gloucestershire.
1864. *Hutton, Darnton. 14 Cumberland-terrace, Regent's Park, N.W.
1887. *Hutton, J. Arthur. The Woodlands, Alderley Edge, Cheshire.
1901. *Hutton, R. S., M.Sc. The Owens College, Manchester.
1883. ‡Hyde, George H. 23 Arbour-street, Southport.
1871. *Hyett, Francis A. Painswick House, Painswick, Stroud, Gloucestershire.
1900. *Hyndman, H. H. Francis. Physical Laboratory, Leiden, Netherlands.

1883. §Idris, T. H. W. Pratt-street, Camden Town, N.W.
Ihne, William, Ph.D. Heidelberg.
1884. *Iles, George. 5 Brunswick-street, Montreal, Canada.
1885. ‡im-Thurn, Everard F., C.B., C.M.G., M.A. British Guiana.
1888. *Ince, Surgeon-Lieut.-Col. John, M.D. Montague House, Swanley, Kent.
1858. ‡Ingham, Henry. Wortley, near Leeds.
1893. ‡Ingle, Herbert. Pool, Leeds.
1901. §INGLIS, JOHN, LL.D. 4 Prince's Terrace, Dowanhill, Glasgow.
1891. ‡Ingram, Lieut.-Colonel C. W. Bradford-place, Penarth.
1852. ‡INGRAM, J. K., LL.D., M.R.I.A., Senior Lecturer in the University of Dublin. 2 Wellington-road, Dublin.

Year of Election.

1885. ‡Ingram, William, M.A. Gamrie, Banff.
1886. ‡*Innes, John. The Limes, Alcester Road, Moseley, Birmingham.*
1898. ‡Inskip, James. Clifton Park, Clifton, Bristol.
1901. *Ionides, Stephen. 23 Second Avenue, Hove, Brighton.
1892. ‡*Ireland, D. W. 10 South Gray Street, Edinburgh.*
1898. ‡Irvine, James. Devonshire-road, Birkenhead.
1892. ‡Irvine, Robert, F.R.S.E. Royston, Granton, Edinburgh.
1882. §IRVING, Rev. A., B.A., D.Sc. Hockerill Vicarage, Bishop's Stortford, Herts.
1888. **Isaac, J. F. V., B.A. Royal York Hotel, Brighton.*
1883. ‡Isherwood, James. 18 York-road, Birkdale, Southport.

1859. ‡Jack, John, M.A. Belhelvie-by-Whitecairns, Aberdeenshire.
1884. †Jack, Peter. People's Bank, Halifax, Nova Scotia, Canada.
1876. *JACK, WILLIAM, LL.D., Professor of Mathematics in the University of Glasgow. 10 The College, Glasgow.
1901. §Jacks, William, LL.D. Crosslet, Dumbartonshire.
1883. *JACKSON, Professor A. H., B.Sc. 358 Collins-street, Melbourne, Australia.
1874. *Jackson, Frederick Arthur. Penalva Ranche, Millarville, Alberta, Calgary, N.W.T., Canada.
1883. *Jackson, F. J. 42 Whitworth-street, Manchester.
1883. †Jackson, Mrs. F. J. 42 Whitworth-street, Manchester.
1899. §Jackson, Geoffrey A. 31 Harrington-gardens, Kensington, S.W.
1885. ‡Jackson, Henry. 19 Golden-square, Aberdeen.
1866. ‡Jackson, H. W., F.R.A.S. 67 Upgate, Louth, Lincolnshire.
1897. §Jackson, James, F.R.Met.Soc. The Avenue, Girvan, N.B.
1898. *Jackson, Sir John. 3 Victoria-street, S.W.
1869. §Jackson, Moses, J.P. The Orchards, Whitchurch, Hants.
1887. §Jacobson, Nathaniel. Olive Mount, Cheetham Hill-road, Manchester.
1874. *Jaffe, John. Villa Jaffe, 38 Prom. des Anglais, Nice, France.
1891. ‡James, Arthur P. Grove House, Park-grove, Cardiff.
1891. *James, Charles Henry. 64 Park-place, Cardiff.
1891. **James, Charles Russell. 6 New-court, Lincoln's Inn, W.C.*
1860. ‡James, Edward H. Woodside, Plymouth.
1886. ‡James, Frank. Portland House, Aldridge, near Walsall.
1891. ‡James, Ivor. University College, Cardiff.
1891. ‡*James, John Herbert. Howard House, Arundel-street, Strand, W.C.*
1891. ‡James, J. R., L.R.C.P. 158 Cowbridge-road, Canton, Cardiff.
1896. †James, O. S. 192 Jarvis-street, Toronto, Canada.
1858. ‡James, William C. Woodside, Plymouth.
1896. **Jameson, H. Lyster. Killencoole, Castlebellingham, Ireland.*
1884. ‡Jameson, W. C. 48 Baker-street, Portman-square, W.
1881. ‡Jamieson, Andrew, Principal of the College of Science and Arts, Glasgow.
1885. ‡Jamieson, Thomas. 173 Union-street, Aberdeen.
1859. *Jamieson, Thomas F., LL.D., F.G.S. Ellon, Aberdeenshire.
1889. *JAPP, F. R., M.A., Ph.D., LL.D., F.R.S. (Pres. B, 1898), Professor of Chemistry in the University of Aberdeen.
1896. *Jarmay, Gustav. Hartford Lodge, Hartford, Cheshire.
1870. ‡Jarrold, John James. London-street, Norwich.
1891. ‡Jefferies, Henry. Plas Newydd, Park-road, Penarth.
1855. *Jeffray, John. 9 Winton-drive, Kelvinside, Glasgow.
1897. ‡Jeffrey, E. C., B.A. The University, Toronto, Canada.
1867. ‡Jeffreys, Howel, M.A. 61 Bedford-gardens, Kensington, W.

Year of Election.

1894. ‡Jelly, Dr. W. Aveleanas, 11, Valencia, Spain.
1891. §Jenkins, Henry C., Assoc.M.Inst.C.E., F.C.S. Royal College of Science, South Kensington, S.W.
1873. §Jenkins, Major-General J. J. 16 St. James's-square, S.W.
1880. *JENKINS, Sir JOHN JONES. The Grange, Swansea.
1899. §Jenkins, Colonel T. M. Glan Tivy, Westwood-road, Southampton.
1852. ‡Jennings, Francis M., M.R.I.A. Brown-street, Cork.
1893. §Jennings, G. E. Glen Helen, Narborough Road, Leicester.
1897. ‡Jennings, W. T., M.Inst.CE. Molson's Bank Buildings, Toronto, Canada.
1899. ‡Jepson, Thomas. Evington, Northumberland-street, Higher Broughton, Manchester.
1887. ‡JERVIS-SMITH, Rev. F J., M.A., F.R.S. Trinity College, Oxford.
Jessop, William. Overton Hall, Ashover, Chesterfield.
1889. ‡Jevons, F. B., M.A. The Castle, Durham.
1900. *Jevons, H. Stanley. 95 Victoria Road, Cambridge.
1884. ‡Jewell, Lieutenant Theo. F. Torpedo Station, Newport, Rhode Island, U.S.A.
1891. ‡*John, E. Cowbridge, Cardiff.*
1884. ‡Johns, Thomas W. Yarmouth, Nova Scotia, Canada.
1884. ‡JOHNSON, ALEXANDER, M.A., LL.D., Professor of Mathematics in McGill University, Montreal. 5 Prince of Wales-terrace, Montreal, Canada.
1883. ‡Johnson, Miss Alice. Llandaff House, Cambridge.
1883. ‡*Johnson, Edmund Litler. 73 Albert Road, Southport.*
1865. *Johnson, G. J. 36 Waterloo-street, Birmingham.
1888. ‡Johnson, J. G. Southwood Court, Highgate, N.
1870. ‡Johnson, Richard C., F.R.A.S. 46 Jermyn-street, Liverpool.
1863. ‡Johnson, R. S. Hanwell, Fence Houses, Durham.
1881. ‡Johnson, Sir Samuel George. Municipal Offices, Nottingham.
1890. *JOHNSON, THOMAS, D.Sc., F.L.S., Professor of Botany in the Royal College of Science, Dublin.
1898. *Johnson, W. Claude, M.Inst.C.E. The Dignaries, Blackheath, S.E.
1887. ‡Johnson, W. H. Woodleigh, Altrincham, Cheshire.
1883. ‡Johnson, W. H. F. Llandaff House, Cambridge.
1883. ‡Johnson, William. Harewood, Roe-lane, Southport.
1861. ‡Johnson, William Beckett. Woodlands Bank, near Altrincham, Cheshire.
1899. §Johnston, Colonel Duncan A., R.E. Ordnance Survey, Southampton.
1883. ‡JOHNSTON, Sir H. H., G.C.M.G., K.C.B., F.R.G.S. Queen Anne's Mansions, S.W.
1859. ‡Johnston, James. Newmill, Elgin, N.B.
1864. ‡Johnston, James. Manor House, Northend, Hampstead, N.W.
1884. ‡Johnston, John L. 27 St. Peter-street, Montreal, Canada.
1883 ‡Johnston, Thomas. Broomsleigh, Seal, Sevenoaks.
1884. ‡Johnston, Walter R. Fort Qu'Appelle, N.W. Territory, Canada.
1884. *Johnston, W. H. County Offices, Preston, Lancashire.
1885. ‡JOHNSTON-LAVIS, H. J., M.D., F.G.S. Beaulieu, Alpes Maritimes, France.
1886. ‡Johnstone, G. H. Northampton-street, Birmingham.
1871. ‡JOLLY, WILLIAM, F.R.S.E., F.G.S. Blantyre Lodge, Blantyre, N.B.
1888. ‡Jolly, W. C. Home Lea, Lansdowne, Bath.
1896. *JOLY, C. J., M.A. The Observatory, Dunsink, Co. Dublin.
1888. ‡JOLY, JOHN, M.A., D.Sc., F.R.S., F.G.S., Professor of Geology and Mineralogy in the University of Dublin.
1898. ‡Jones, Sir Alfred L., K.C.M.G. Care of Messrs. Elder, Dempster, & Co., Liverpool.

Year of Election.

1887. ‡Jones, D. E., B.Sc., H.M. Inspector of Schools. Science and Art Department, South Kensington, S.W.
1901. §Jones, R. E., J.P. Radnor House, Shrewsbury.
1890. §JONES, Rev. EDWARD, F.G.S. Primrose Cottage, Embsay, Skipton.
1891. ‡Jones, Dr. Evan. Aberdare.
1896. ‡Jones, E. Taylor, D.Sc. University College, Bangor.
1887. ‡Jones, Francis, F.R.S.E., F.C.S. Beaufort House, Alexandra Park, Manchester.
1891. *JONES, Rev. G. HARTWELL, M.A. Nutfield Rectory, Redhill, Surrey.
1883. *Jones, George Oliver, M.A. Inchyra House, 21 Cambridge Road, Waterloo, Liverpool.
1895. ‡Jones, Harry. Engineer's Office, Great Eastern Railway, Ipswich.
1877. ‡Jones, Henry C., F.C.S. Royal College of Science, South Kensington, S.W.
1873. ‡Jones, Theodore B. 1 Finsbury-circus, E.C.
1880. ‡Jones, Thomas. 15 Gower-street, Swansea.
1860. ‡JONES, THOMAS RUPERT, F.R.S., F.G.S. (Pres. C, 1891). 17 Parson's Green, Fulham, S.W.
1896. §Jones, W. Hope Bank, Lancaster-road, Pendleton, Manchester.
1883. ‡Jones, William. Elsinore, Birkdale, Southport.
1875. *Jose, J. E. 49 Whitechapel, Liverpool.
1884. ‡Joseph, J. H. 738 Dorchester-street, Montreal, Canada.
1891. ‡Jotham, F. H. Penarth.
1891. ‡Jotham, T. W. Penylan, Cardiff.
1879. ‡Jowitt, A. Scotia Works, Sheffield.
1890. ‡Jowitt, Benson R. Elmhurst, Newton-road, Leeds.
1872. ‡Joy, Algernon. Junior United Service Club, St. James's, S.W.
1883. ‡Joyce, Rev. A. G., B.A. St. John's Croft, Winchester.
1886. ‡Joyce, The Hon. Mrs. St. John's Croft, Winchester.
1891. ‡Joynes, John J. Great Western Colliery, near Coleford, Gloucestershire.
1848. **Jubb, Abraham. Halifax.*
1870. ‡JUDD, JOHN WESLEY, C.B., F.R.S., F.G.S. (Pres. C, 1885; Council, 1886–92), Professor of Geology in the Royal College of Science, London. 22 Cumberland-road, Kew.
1883. ‡Justice, Philip Middleton. 14 Southampton-buildings, Chancery-lane, W.C.

1888. ‡Kapp, Gisbert, M.Inst.C.E., M.Inst.E.E. 3 Lindenallee, Westend, Berlin.
1884. ‡Keefer, Samuel. Brockville, Ontario, Canada.
1875. ‡Keeling, George William. Tuthill, Lydney.
1886. ‡Keen, Arthur, J.P. Sandyford, Augustus-road, Birmingham.
1894. ‡*Keene, Captain C. T. P., F.Z.S. 11 Queen's-gate, S.W.*
1894. ‡Keightley, Rev. G. W. Great Stambridge Rectory, Rochford, Essex.
1878. *Kelland, W. H. North Street, Exeter.
1884. ‡Kellogg, J. H., M.D. Battle Creek, Michigan, U.S.A.
1864. *Kelly, W. M., M.D. Ferring, near Worthing.
1885. §KELTIE, J. SCOTT, LL.D., Sec. R.G.S., F.S.S. (Pres. E, 1897; Council, 1898–). 1 Savile-row, W.
1847. *KELVIN, The Right Hon. Lord, G.C.V.O., M.A., LL.D., D.C.L., F.R.S., F.R.S.E., F.R.A.S. (PRESIDENT, 1871; Pres. A, 1852, 1867, 1876, 1881, 1884). Netherhall, Largs, Ayrshire.
1877. *Kelvin, Lady. Netherhall, Largs, Ayrshire.
1887. ‡Kemp, Harry. 55 Wilbraham-road, Chorlton-cum-Hardy, Manchester.

Year of Election.

1898. *Kemp, John T., M.A. 4 Cotham Grove, Bristol.
1884. ‡Kemper, Andrew C., A.M., M.D. 101 Broadway, Cincinnati, U.S.A.
1890. §Kempson, Augustus. Kildare, 17 Arundel-road, Eastbourne.
1891. §KENDALL, PERCY F., F.G.S., Professor of Geology in Yorkshire College, Leeds.
1875. ‡KENNEDY, ALEXANDER B. W., F.R.S., M.Inst.C.E. (Pres. G, 1894). 17 Victoria-street, S.W., and 1 Queen Anne-street, Cavendish-square, W.
1897. §Kennedy, George, M.A., LL.D. Crown Lands Department, Toronto, Canada.
1884. ‡Kennedy, George T., M.A., F.G.S., Professor of Chemistry and Geology in King's College, Windsor, Nova Scotia, Canada.
1876. ‡Kennedy, Hugh. 20 Mirkland-street, Glasgow.
1884. ‡Kennedy, John. 113 University-street, Montreal, Canada.
1884. ‡Kennedy, William. Hamilton, Ontario, Canada.
1886. ‡Kenrick, George Hamilton. Whetstone, Somerset-road, Edgbaston, Birmingham.
1893. §KENT, A. F. STANLEY, M.A., F.L.S., F.G.S., Professor of Physiology in University College, Bristol.
1901. §Kent, G. 19 Forest Road West, Nottingham.
1886. §KENWARD, JAMES, F.S.A. 43 Streatham High-road, S.W.
1857. *Ker, André Allen Murray. Newbliss House, Newbliss, Ireland.
1876. ‡Ker, William. 1 Windsor-terrace West, Glasgow.
1881. ‡KERMODE, PHILIP M. C. Hillside, Ramsey, Isle of Man.
1884. ‡Kerr, James, M.D. Winnipeg, Canada.
1883. ‡KERR, REV. JOHN, LL.D., F.R.S. Free Church Training College; 113 Hill-street, Glasgow.
1901. §Kerr, John G., LL.D. 15 India Street, Glasgow.
1892. ‡Kerr, J. Graham, M.A. Christ's College, Cambridge.
1889. ‡Kerry, W. H. R. The Sycamores, Windermere.
1887. ‡Kershaw, James. Holly House, Bury New-road, Manchester.
1869. *Kesselmeyer, Charles Augustus. Rose Villa, Vale-road, Bowdon, Cheshire.
1869. *Kesselmeyer, William Johannes. Elysée Villa, Manchester Road, Altrincham, Cheshire.
1883. *Keynes, J. N., M.A., D.Sc., F.S.S. 6 Harvey-road, Cambridge.
1876. ‡Kidston, J. B. 50 West Regent-street, Glasgow.
1886. §KIDSTON, ROBERT, F.R.S.E., F.G.S. 12 Clarendon-place, Stirling.
1897. ‡Kiekelly, Dr. John, LL.D 46 Upper Mount-street, Dublin.
1901. §Kiep, J. W. 4 Hughenden Drive, Kelvinside, Glasgow.
1885. *Kilgour, Alexander. Loirston House, Cove, near Aberdeen.
1896. *Killey, George Deane. Bentuther, 11 Victoria-road, Waterloo, Liverpool.
1890. §KIMMINS, C. W., M.A., D.Sc. Bermondsey Settlement Lodge, Farncombe Street, S.E.
1878. ‡Kinahan, Sir Edward Hudson, Bart. 11 Merrion-square North, Dublin.
1860. ‡KINAHAN, G. HENRY, M.R.I.A. Dublin.
1875. *KINCH, EDWARD, F.C.S. Royal Agricultural College, Cirencester.
1888. ‡King, Austin J. Winsley Hill, Limpley Stoke, Bath.
1888. *King, E. Powell. Wainsford, Lymington, Hants.
1875. *King, F. Ambrose. Avonside, Clifton, Bristol.
1899. ‡KING, Sir GEORGE, K.C.I.E., F.R.S. (Pres. K, 1899). Care of Messrs. Grindlay & Co., 55 Parliament-street, S.W.
1871. *King, Rev. Herbert Poole. The Rectory, Stourton, Bath.

Year of Election.

1855. ‡King, James. Levernholme, Hurlet, Glasgow.
1883. *King, John Godwin. Stonelands, West Hoathley.
1870. ‡King, John Thomson. 4 Clayton-square, Liverpool.
1883. *King, Joseph. Lower Birtley, Witley, Godalming.
1860. *King, Mervyn Kersteman. Merchants' Hall, Bristol.
1875. *King, Percy L. 2 Worcester-avenue, Clifton, Bristol.
1901. §King, Robert. Levernholme, Nitshill, Glasgow.
1870. ‡King, William. 5 Beach Lawn, Waterloo, Liverpool.
1889. ‡King, Sir William. Stratford Lodge, Southsea.
1897. ‡Kingsmill, Nichol. Toronto, Canada.
1875. ‡Kingzett, Charles T., F.C.S. Elmstead Knoll, Chislehurst.
1867. ‡Kinloch, Colonel. Kirriemuir, Logie, Scotland.
1892. ‡Kinnear, The Hon. Lord, F.R.S.E. 2 Moray Place, Edinburgh.
1900. §Kipping, Professor F. Stanley, D.Sc., Ph.D., F.R.S. University College, Nottingham.
1899. *Kirby, Miss C. F. 74 Kensington Park-road, W.
1899. *Kirby, Miss M. A. Field House, Richmond Road, Montpelier, Bristol.
1870. ‡Kitchener, Frank E. Newcastle, Staffordshire.
1890. *Kitson, Sir James, Bart., M.P. Gledhow Hall, Leeds.
1901. §Kitto, Edward. The Observatory, Falmouth.
1886. ‡Klein, Rev. L. M. de Beaumont, D.Sc., F.L.S. 6 Devonshire-road, Liverpool.
1886. ‡Knight, J. McK., F.G.S. Bushwood, Wanstead, Essex.
1898. ‡Knocker, Sir E. Wollaston, K.C.B. (Local Sec. 1899). Castle Hill House, Dover.
1888. ‡Knott, Professor Cargill G., D.Sc., F.R.S.E. 42 Upper Gray Street, Edinburgh.
1887. *Knott, Herbert. Aingarth, Stalybridge, Cheshire.
1887. *Knott, John F. Glan-y-Coed, Conway.
1887. ‡Knott, Mrs. Glan-y-Coed, Conway.
1874. ‡Knowles, William James. Flixton-place, Ballymena, Co. Antrim.
1897. ‡Knowlton, W. H. 33 King-street East, Toronto, Canada.
1876. ‡Knox, David N., M.A., M.B. 24 Elmbank-crescent, Glasgow.
1902. §Knox, R. Kyle, LL.D. (Local Treasurer, 1902). 1 College Gardens, Belfast.
1875. *Knubley, Rev. E. P., M.A. Steeple Ashton Vicarage, Trowbridge.
1883. ‡Knubley, Mrs. Steeple Ashton Vicarage, Trowbridge.
1892. ‡Kohn, Charles A., Ph.D. Sir John Cass Technical Institute, Aldgate, E.
1898. ‡Krauss, A. Hawthornden, Priory-road, Clifton, Bristol.
1890. *Krauss, John Samuel, B.A. Hodnet, Salop.
1901. §Kuenen, Professor J. P., Ph. D. University College, Dundee.
1888. *Kunz, G. F. Care of Messrs. Tiffany & Co., 11 Union-square, New York City, U.S.A.
1870. ‡Kynaston, Josiah W., F.C.S. 3 Oak-terrace, Beech-street, Liverpool.

1858. ‡Lace, Francis John. Stone Gapp, Cross Hill, Leeds.
1884. ‡Laflamme, Rev. Professor J. C. K. Laval University, Quebec.
1885. *Laing, J. Gerard. Coppens Wick, Clapton-on-Sea, Essex.
1897. ‡Laird, Professor G. J. Wesley College, Winnipeg, Canada.
1877. ‡Lake, W. C., M.D. Teignmouth.
1859. ‡Lalor, John Joseph, M.R.I.A. City Hall, Cork Hill, Dublin.
1889. *Lamb, Edmund, M.A. Borden Wood, Liphook, Hants.
1887. ‡Lamb, Horace, M.A., F.R.S., Professor of Pure Mathematics in the Owens College, Manchester. 6 Wilbraham-road, Fallowfield, Manchester.

Year of Election.

1887. ‡Lamb, James. Kenwood, Bowdon, Cheshire.
1883. ‡Lamb, W. J. 11 Gloucester-road, Birkdale, Southport.
1896. §Lambert, Frederick Samuel. Balgowan, Newland, Lincoln.
1893. ‡Lambert, J. W., J.P. Lenton Firs, Nottingham.
1884. †Lamborn, Robert H. Montreal, Canada.
1893. ‡LAMPLUGH, G. W., F.G.S. Geological Survey Office, 14 Hume Street, Dublin.
1890. ‡Lamport, Edward Parke. Greenfield Well, Lancaster.
1884. ‡Lancaster, Alfred. Fern Bank, Burnley, Lancashire.
1871. †Lancaster, Edward. Karesforth Hall, Barnsley, Yorkshire.
1886. ‡Lancaster, W. J., F.G.S. Colmore-row, Birmingham.
1877. ‡Landon, Frederic George, M.A., F.R.A.S. 59 Tresillian-road, St. John's, S.E.
1883. ‡Lang, Rev. Gavin. Mayfield, Inverness.
1859. ‡Lang, Rev. John Marshall, D.D. The University, Aberdeen.
1898. *Lang, William H. 10 Jedburgh-gardens, Kelvinside, Glasgow.
1886. *LANGLEY, J. N., M.A., D.Sc., F.R.S. (Pres. I, 1899). Trinity College, Cambridge.
1870. ‡Langton, Charles. Barkhill, Aigburth, Liverpool.
1865. ‡LANKESTER, E. RAY, M.A., LL.D., F.R.S. (Pres. D, 1883; Council 1889–90, 1894–95, 1900– ; VICE-PRESIDENT, 1902). Director of the Natural History Museum, Cromwell-road, S.W.
1880. *LANSDELL, Rev. HENRY, D.D., F.R.A.S., F.R.G.S. Morden College, Blackheath, London, S.E.
1884. §Lanza, Professor G. Massachusetts Institute of Technology, Boston, U.S.A.
1878. ‡Lapper, E., M.D. 61 Harcourt-street, Dublin.
1885. ‡LAPWORTH, CHARLES, LL.D., F.R.S., F.G.S. (Pres. C, 1892), Professor of Geology and Physiography in the University, Birmingham. 28 Duchess-road, Edgbaston, Birmingham.
1887. ‡Larmor, Alexander. Craglands, St. Helen's, Co. Down.
1881. ‡LARMOR, JOSEPH, M.A., D.Sc., Sec.R.S. (Pres. A, 1900). St. John's College, Cambridge.
1883. §Lascelles, B. P., M.A. Longridge, Harrow.
1896. *Last, William J. South Kensington Museum, London, S.W.
1870. *LATHAM, BALDWIN, M.Inst.C.E., F.G.S. 7 Westminster-chambers, Westminster, S.W.
1900. §Lauder, Alexander. University College, Bangor.
1870. ‡Laughton, John Knox, M.A., F.R.G.S. 5 Pepys-road, Wimbledon, Surrey.
1891. ‡Laurie, A. P. Heriot Watt College, Edinburgh.
1892. §LAURIE, MALCOLM, B.A., D.Sc., F.L.S., Professor of Zoology in St. Mungo's College, Glasgow.
1888. ‡Laurie, Colonel R. P., C.B. 79 Farringdon-street, E.C.
1883. ‡Laurie, Major-General. Oakfield, Nova Scotia, Canada.
1870. *Law, Channell. Ilsham Dene, Torquay.
1878. ‡Law, Henry, M.Inst.C.E. 9 Victoria-chambers, S.W.
1884. §Law, Robert, F.G.S. Fennyroyd Hall, Hipperholme, near Halifax, Yorkshire.
1870. ‡Lawrence, Edward. Aigburth, Liverpool.
1881. ‡Lawrence, Rev. F., B.A. The Vicarage, Westow, York.
1900. §Lawrence, W. Trevor, Ph.D. 57 Prince's Gate, S.W.
1889. §Laws, W. G., M.Inst.C.E. 65 Osborne-road, Newcastle-upon-Tyne.
1885. ‡Lawson, James. 8 Church-street, Huntly, N.B.
1888. ‡Layard, Miss Nina F. 2 Park-place, Fonnereau-road, Ipswich.
1856. ‡Lea, Henry. 38 Bennett's-hill, Birmingham.
1883. *Leach, Charles Catterall. Seghill, Northumberland.

Year of
Election.
1875. ‡Leach, Colonel Sir G., K.C.B., R.E. 6 Wetherby-gardens, S.W.
1894. *Leahy, A. H., M.A., Professor of Mathematics in University College. 92 Ashdell-road, Sheffield.
1884. *Leahy, John White, J.P. South Hill, Killarney, Ireland.
1901. *Lean, George, B.Sc. 15 Park Terrace, Glasgow.
1884. ‡Learmont, Joseph B. 120 Mackay-street, Montreal, Canada.
1884. *Leavitt, Erasmus Darwin. 2 Central-square, Cambridgeport, Massachusetts, U.S.A.
1872. ‡Lebour, G. A., M.A., F.G.S., Professor of Geology in the College of Physical Science, Newcastle-on-Tyne.
1884. ‡Leckie, R. G. Springhill, Cumberland County, Nova Scotia, Canada.
1895. *Ledger, Rev. Edmund. Proted, Woods-road, Reigate.
1898. §Lee, Arthur, J.P. (Local Sec. 1898). 10 Berkeley-square, Clifton, Bristol.
1896. §Lee, Rev. H. J. Barton. 35 Cross Park Terrace, Heavitree, Exeter.
1891. ‡Lee, Mark. The Cedars, Llandaff-road, Cardiff.
1894. *Lee, Mrs. W. Ashdown House, Forest Row, Sussex.
1884. *Leech, Sir Bosdin T. Oak Mount, Timperley, Cheshire.
1896. *Leech, Lady. Oak Mount, Timperley, Cheshire.
1892. *Lees, Charles H., D.Sc. Osborne, Belgrave-road, Oldham.
1886. *Lees, Lawrence W. Old Ivy House, Tettenhall, Wolverhampton
1859. ‡Lees, William, M.A. 12 Morningside-place, Edinburgh.
1896. ‡Lees, William. 10 Norfolk-street, Manchester.
*Leese, Joseph. 3 Lord-street West, Southport.
1889. *Leeson, John Rudd, M.D., C.M., F.L.S., F.G.S. Clifden House, Twickenham, Middlesex.
1881. ‡Le Feuvre, J. E. Southampton.
1872. ‡Lefevre, The Right Hon. G. Shaw, F.R.S. (Pres. F, 1879; Council 1878–80). 18 Bryanston-square, W.
1869. ‡Le Grice, A. J. Trereife, Penzance.
1892. †Lehfeldt, Robert A. 28 South Molton-street, W.
1868. ‡Leicester, The Right Hon. the Earl of, K.G. Holkham, Norfolk.
1856. ‡Leigh, The Right Hon. Lord. Stoneleigh Abbey, Kenilworth.
1891. ‡Leigh, W. W. Treharris, R.S.O., Glamorganshire.
1859. ‡Leith, Alexander. Glenkindie, Inverkindie, N.B.
1882. §Lemon, James, M.Inst.C.E., F.G.S. Lansdowne House, Southampton.
1867. ‡Leng, Sir John, M.P. 'Advertiser' Office, Dundee.
1878. ‡Lennon, Rev. Francis. The College, Maynooth, Ireland.
1887. *Leon, John T. Elmwood, Grove Road, Southsea.
1871. ‡Leonard, Hugh, M.R.I.A. 24 Mount Merrion-avenue, Blackrock, Co. Dublin.
1901. §Leonard, J. H. Paradise House, Stoke Newington, N.
1884. ‡Lesage, Louis. City Hall, Montreal, Canada.
1890. *Lester, Joseph Henry. Royal Exchange, Manchester.
1883. ‡Lester, Thomas. Fir Bank, Penrith.
1880. ‡Letcher, R. J. Lansdowne-terrace, Walters-road, Swansea.
1900. §Letts, Professor E. A. Queen's College, Belfast.
1894. ‡Leudesdorf, Charles. Pembroke College, Oxford.
1896. ‡Lever, W. H. Port Sunlight, Cheshire.
1887. *Levinstein, Ivan. Hawkesmoor, Fallowfield, Manchester.
1890. ‡Levy, J. H. 11 Abbeville-road, Clapham Park, S.W.
1893. *Lewes, Vivian B., F.C.S., Professor of Chemistry in the Royal Naval College, Greenwich, S.E.
1879. ‡Lewin, Colonel, F.R.G.S. Garden Corner House, Chelsea Embankment, S.W.
1870. ‡Lewis, Alfred Lionel. 54 Highbury-hill, N.
1891. ‡Lewis, D., J.P. 44 Park-place, Cardiff.

Year of Election.

1891. §Lewis, Professor D. Morgan, M.A. University College, Aberystwyth.
1899. ‡Lewis, Professor E. P. University of California, Berkeley, U.S.A.
1897. §Lewis, Rev. J. Pitt, M.A. Rossin House, Toronto, Canada.
1899. ‡Lewis, Thomas. 9 Hubert-terrace, Dover.
1891. ‡Lewis, W. 22 Duke-street, Cardiff.
1891. ‡Lewis, W. Henry. Bryn Rhos, Llanishen, Cardiff.
1884. *Lewis, Sir W. T., Bart. The Mardy, Aberdare.
1878. ‡Lincolne, William. Ely, Cambridgeshire.
1901. §Lindsay, Charles C., M.Inst.C.E. 217 West George Street, Glasgow.
1871. ‡Lindsay, Rev. T. M., M.A., D.D. Free Church College, Glasgow.
1898. §Lippincott, R. C. Cann. Over Court, Almondsbury, near Bristol.
1883. ‡Lisle, H. Claud. Nantwich.
1895. *Lister, The Right Hon. Lord, F.R.C.S., D.C.L., F.R.S. (President, 1896). 12 Park-crescent, Portland-place, W.
1888. ‡Lister, J. J., M.A., F.R.S. Leytonstone, Essex, N.E.
1861. *Liveing, G. D., M.A., F.R.S. (Pres. B, 1882; Council 1888-95; Local Sec. 1862), Professor of Chemistry in the University of Cambridge. Newnham, Cambridge.
1876. *Liversidge, Archibald, M.A., F.R.S., F.C.S., F.G.S., F.R.G.S., Professor of Chemistry in the University of Sydney, N.S.W.
1880. ‡Llewelyn, Sir John T. D., Bart., M.P. Penllegare, Swansea.
1865. ‡Lloyd, G. B., J.P. Edgbaston-grove, Birmingham.
1886. ‡Lloyd, J. Henry. Ferndale, Carpenter-road, Edgbaston, Birmingham.
1891. *Lloyd, R. J., M.A., D.Litt., F.R.S.E. 49a Grove-street, Liverpool.
1886. ‡Lloyd, Samuel. Farm, Sparkbrook, Birmingham.
1865. *Lloyd, Wilson, F.R.G.S. Park Lane House, Woodgreen, Wednesbury.
1897. §Lloyd-Verney, J. H. 14 Hinde-street, Manchester-square, W.
1854. *Lobley, J. Logan, F.G.S. City of London College, Moorfields, E.C.
1892. §Loch, C. S., B.A. 15a Buckingham-street, W.C.
1867. *Locke, John. 144 St. Olaf's-road, Fulham, S.W.
1892. ‡Lockhart, Robert Arthur. 10 Polwarth-terrace, Edinburgh.
1863. ‡Lockyer, Sir J. Norman, K.C.B., F.R.S. (Council 1871-76, 1901-). 16 Penywern Road, S.W.
1900. §Lockyer, W. J. S. 16 Penywern Road, South Kensington, S.W.
1886. *Lodge, Alfred, M.A., Professor of Pure Mathematics in the Royal Indian Civil Engineering College, Cooper's Hill, Staines.
1875. *Lodge, Oliver J., D.Sc., LL.D., F.R.S. (Pres. A, 1891; Council 1891-97, 1899-), Principal of the University of Birmingham.
1894. *Lodge, Oliver W. F. 225 Hagley Road, Birmingham.
1889. ‡Logan, William. Langley Park, Durham.
1896. §Lomas, J., F.G.S. 13 Moss Grove, Birkenhead.
1899. §Loncq, Emile. 6 Rue de la Plaine, Laon, Aisne, France.
1902. §§Londonderry, the Marquess of, K.G., H.M. Lieutenant of the City of Belfast (Vice-President, 1902).
1876. ‡Long, H. A. Brisbane, Queensland.
1883. *Long, William. Thelwall Heys, near Warrington.
1883. ‡Long, Mrs. Thelwall Heys, near Warrington.
1883. ‡Long, Miss. Thelwall Heys, near Warrington.
1866. ‡Longdon, Frederick. Osmaston-road, Derby.
1901. §Longe, Francis D. The Alders, Marina, Lowestoft.
1898. *Longfield, Miss Gertrude. High Halston Rectory, Rochester.
1901. *Longstaff, Frederick V., F.R.G.S. Clare College, Cambridge.
1875. *Longstaff, George Blundell, M.A., M.D., F.C.S., F.S.S. Highlands, Putney Heath, S.W.
1872. *Longstaff, Llewellyn Wood, F.R.G.S. Ridgelands, Wimbledon.

Year of Election.

1881. *Longstaff, Mrs. Ll. W. Ridgelands, Wimbledon, Surrey.
1899. *Longstaff, Tom G., B.A., F.R.Met.Soc. Ridgelands, Wimbledon, Surrey.
1883. *Longton, E. J., M.D. Brown House, Blawith, *viâ* Ulverston.
1894. ‡Lord, Edwin C. E., Ph.D. 247 Washington-street, Brooklyn, U.S.A.
1889. ‡Lord, Riley. 75 Pilgrim-street, Newcastle-upon-Tyne.
1897. ‡Loudon, James, LL.D., President of the University of Toronto, Canada.
1883. *Louis, D. A., F.C.S. 77 Shirland-gardens, W.
1896. §Louis, Henry, Professor of Mining, Durham College of Science, Newcastle-on-Tyne.
1887. *Love, Professor A. E. H., M.A., F.R.S. 34 St. Margaret's Road, Oxford.
1886. *Love, E. F. J., M.A. The University, Melbourne, Australia.
1876. *Love, James, F.R.A.S., F.G.S., F.Z.S. 33 Clanricarde-gardens, W.
1883. ‡Love, James Allen. 8 Eastbourne-road West, Southport.
1892. §Lovibond, J. W. Salisbury, Wiltshire.
1889. ‡*Low, Charles W. 84 Westbourne Terrace, W.*
1867. *Low, James F. Seaview, Monifieth, by Dundee.
1885. §Lowdell, Sydney Poole. Baldwin's Hill, East Grinstead, Sussex.
1891. ‡Lowdon, John. St. Hilda's, Barry, Glamorgan.
1885. *Lowe, Arthur C. W. Gosfield Hall, Halstead, Essex.
1892. ‡Lowe, D. T. Heriot's Hospital, Edinburgh.
1886. *Lowe, John Landor, B.Sc., M.Inst.C.E. Strathavon, Kedleston Road, Derby.
1894. ‡Lowenthal, Miss Nellie. 60 New North-road, Huddersfield.
1881. ‡Lubbock, Arthur Rolfe High Elms, Farnborough, R.S.O., Kent.
1881. ‡Lubbock, John B. 14 Berkeley-street, W.
1870. ‡Lubbock, Montague, M.D. 19 Grosvenor-street, W.
1901. *Lucas, Keith. Greenhall, Forest Row, Sussex.
1889. ‡Lucas, John. 1 Carlton-terrace, Low Fell, Gateshead.
1878. ‡Lucas, Joseph. Tooting Graveney, S.W.
1889. ‡Luckley, George. The Grove, Jesmond, Newcastle-upon-Tyne.
1891. *Lucovich, Count A. The Rise, Llandaff.
1881. ‡Luden, C. M. 4 Bootham-terrace, York.
1897. ‡Lumsden, George E., F.R.A.S. 57 Elm-avenue, Toronto, Canada.
1866. *Lund, Charles. Ilkley, Yorkshire.
1873. ‡Lund, Joseph. Ilkley, Yorkshire.
1850. *Lundie, Cornelius. 32 Newport-road, Cardiff.
1892. ‡Lunn, Robert. Geological Survey Office, Sheriff Court House, Edinburgh.
1853. ‡Lunn, William Joseph, M.D. 23 Charlotte-street, Hull.
1883. *Lupton, Arnold, M.Inst.C.E., F.G.S., Professor of Coal Mining in Yorkshire College, Leeds. 6 De Grey-road, Leeds.
1874. *Lupton, Sydney, M.A. (Local Sec. 1890). 102 Park Street, Grosvenor Square, W.
1900. ‡Lupton, William C. Bradford.
1864. *Lutley, John. Brockhampton Park, Worcester.
1898. §Luxmoore, Dr. C. M. Reading College, Reading.
1871. ‡Lyell, Sir Leonard, Bart., F.G.S. 48 Eaton-place, S.W.
1899. ‡Lyle, Professor Thomas R. The University, Melbourne.
1884. ‡Lyman, A. Clarence. 84 Victoria-street, Montreal, Canada.
1884. ‡Lyman, H. H. 74 McTavish-street, Montreal, Canada.
1874. ‡Lynam, James. Ballinasloe, Ireland.
1885. ‡Lyon, Alexander, jun. 52 Carden-place, Aberdeen.
1896. ‡Lyster, A. G. Dockyard Coburg Dock, Liverpool.
1862. *Lyte, F. Maxwell, M.A., F.C.S. 60 Finborough-road, S.W.

Year of Election.

1876. *MACADAM, WILLIAM IVISON, F.R.S.E., F.I.C., F.C.S. Surgeons' Hall, Edinburgh.
1868. ‡MACALISTER, ALEXANDER, M.A., M.D., F.R.S. (Pres. H, 1892; Council, 1901–), Professor of Anatomy in the University of Cambridge. Torrisdale, Cambridge.
1878. ‡MACALISTER, DONALD, M.A., M.D., B.Sc. St. John's College, Cambridge.
1896. ‡Macalister, R. A. S. 2 Gordon-street, W.C.
1897. ‡McAllister, Samuel. 99 Wilcox-street, Toronto, Canada.
1896. §MACALLUM, Professor A. B., Ph.D. (Local Sec. 1897). 59 St. George-street, Toronto, Canada.
1879. §MacAndrew, James J., F.L.S. Lukesland, Ivybridge, South Devon.
1883. ‡MacAndrew, Mrs. J. J. Lukesland, Ivybridge, South Devon.
1883. §MacAndrew, William. Westwood House, near Colchester.
1866. *M'Arthur, Alexander. 79 Holland-park, W.
1896. ‡McArthur, Charles. Villa Marina, New Brighton, Cheshire.
1884. ‡Macarthur, D. Winnipeg, Canada.
1896. *Macaulay, F. S., M.A. 19 Dewhurst-road, W.
1834. MACAULAY, JAMES, A.M., M.D. 4 Wynnstay-gardens, W.
1896. ‡MACBRIDE, Professor E. W., M.A. McGill University, Montreal, Canada.
1884. ‡McCabe, T., Chief Examiner of Patents. Patent Office, Ottawa, Canada.
1886. ‡MacCarthy, Rev. E. F. M., M.A. 93 Hagley-road, Birmingham.
1887. *McCarthy, James. Bangkok, Siam.
1884. *McCarthy, J. J., M.D. 83 Wellington-road, Dublin.
1884. ‡McCausland, Orr. Belfast.
1891. *McCLEAN, FRANK, M.A., LL.D., F.R.S., M.Inst.C.E. Rusthall House, Tunbridge Wells.
1876. *M'CLELLAND, A. S. 4 Crown-gardens, Dowanhill, Glasgow.
1868. ‡M'CLINTOCK, Admiral Sir FRANCIS L., R.N., K.C.B., F.R.S., F.R.G.S. United Service Club, Pall Mall, S.W.
*1878. *M'Comas, Henry. Pembroke House, Pembroke Road, Dublin.*
1901. *MacConkey, Alfred. University College, Liverpool.
1901. §MacCormac, J.M., M.D. 31 Victoria Place, Belfast.
1892. *McCowan, John, M.A., D.Sc. Henderson Street, Bridge of Allan, N.B.
1892. ‡McCrae, George. 3 Dick-place, Edinburgh.
1901. §McCrae, John, Ph.D. 7 Kirklee Gardens, Glasgow.
1899. ‡McDiarmid, Jabez. The Elms, Stanmore, Middlesex.
1900. §Macdonald, J. R. 3 Lincoln's Inn Fields, W.C.
1890. *MacDonald, Mrs. J. R. 3 Lincoln's Inn Fields, W.C.
1886. ‡McDonald, John Allen. Hillsboro' House, Derby.
1884. ‡MacDonald, Kenneth. Town Hall, Inverness.
1884. *McDonald, Sir W. C. 891 Sherbrooke-street, Montreal, Canada.
1884. ‡MacDonnell, Mrs. F. H. 1433 St. Catherine-street, Montreal, Canada.
MacDonnell, Hercules H. G. 2 Kildare-place, Dublin.
1884. ‡McDougall, John. 35 St. François Xavier-street, Montreal, Canada.
1897. ‡McEwen, William C. 9 South Charlotte-street, Edinburgh.
1881. ‡Macfarlane, Alexander, D.Sc., F.R.S.E., Professor of Physics in the University of Texas. Austin, Texas, U.S.A.
1885. ‡Macfarlane, J. M., D.Sc., F.R.S.E., Professor of Biology in the University of Pennsylvania, Lansdowne, Delaware Co., Pennsylvania, U.S.A.
1897. ‡McFarlane, Murray, M.D. 32 Carlton-street, Toronto, Canada.
1879. ‡Macfarlane, Walter, jun. 12 Lynedoch-crescent, Glasgow.
1901. §Macfee, John. Marguerite, Blackhall, Paisley.

Year of Election.

1867. *M'Gavin, Robert. Ballumbie, Dundee.
1897. †McGaw, Thomas. Queen's Hotel, Toronto, Canada.
1888 ‡MacGeorge, James. 67 Marloes-road, Kensington, W.
1884. †MacGillivray, James. 42 Cathcart-street, Montreal, Canada.
1884. †MacGoun, Archibald, jun., B.A., B.C.L. Dunavon, Westmount, Montreal, Canada.
1884. *MacGregor, James Gordon, M.A., D.Sc., F.R.S., F.R.S.E., Professor of Natural Philosophy, The University, Edinburgh.
1885. ‡M'Gregor-Robertson, J., M.A., M.B. 26 Buchanan-street, Hillhead, Glasgow.
1867. *McIntosh, W. C., M.D., LL.D., F.R.S., F.R.S.E., F.L.S. (Pres. D, 1885), Professor of Natural History in the University of St. Andrews. 2 Abbotsford-crescent, St. Andrews, N.B.
1884. ‡McIntyre, John, M.D. Odiham, Hants.
1883. ‡Mack, Isaac A. Trinity-road, Bootle.
1884. §MacKay, A. H., B.Sc., LL.D., Superintendent of Education. Education Office, Halifax, Nova Scotia, Canada.
1885. §Mackay, John Yule, M.D., Professor of Anatomy in University College, Dundee.
1897. ‡McKay, T. W G., M.D. Oshawa, Ontario, Canada.
1896. *McKechnie, Duncan. Eccleston Grange, Preston.
1873. ‡McKendrick, John G., M.D., LL.D., F.R.S., F.R.S.E. (Pres. I, 1901), Professor of Physiology in the University of Glasgow. 2 Buckingham Terrace, Glasgow.
1883. ‡McKendrick, Mrs. 2 Florentine-gardens, Glasgow.
1897. ‡McKenzie, John J. 61 Madison-avenue, Toronto, Canada.
1884. ‡MacKenzie, Stephen, M.D. 18 Cavendish Square, W.
1884. ‡McKenzie, Thomas, B.A. School of Science, Toronto, Canada.
1901. §Mackenzie, Thomas Brown. 342 Duke Street, Glasgow.
1883. ‡Mackeson, Henry. Hythe, Kent.
1872. *Mackey, J. A. 175 Grange-road, S.E.
1867. ‡Mackie, Samuel Joseph. 17 Howley-place, W.
1901. §Mackie, William, M.D. 13 North Street, Elgin.
1884. ‡McKilligan, John B. 387 Main-street, Winnipeg, Canada.
1887. ‡Mackinder, H. J., M.A., F.R.G.S. (Pres. E, 1895). Christ Church, Oxford.
1891. †Mackintosh, A. C. 88 Plymouth Road, Penarth.
1850. ‡Macknight, Alexander. 20 Albany-street, Edinburgh.
1872. *McLachlan, Robert, F.R.S., F.L.S. West View, Clarendon-road, Lewisham, S.E.
1896. †Maclagan, Miss Christian. Ravenscroft, Stirling.
1892. ‡Maclagan, Philip R. D. St. Catherine's, Liberton, Midlothian.
1892. ‡Maclagan, R. Craig, M.D., F.R.S.E. 5 Coates-crescent, Edinburgh.
1885. *M'Laren, The Hon. Lord, F.R.S.E., F.R.A.S. 46 Moray-place, Edinburgh.
1860. ‡Maclaren, Archibald. Summertown, Oxfordshire.
1901. §Maclaren, J. Malcolm. 62 Sydney Street, South Kensington, S.W.
1897. ‡MacLaren, J. F. 380 Victoria-street, Toronto, Canada.
1873. ‡MacLaren, Walter S. B. Newington House, Edinburgh.
1897. ‡MacLaren, Rev. Wm., D.D. 57 St. George-street, Toronto, Canada.
1901. §Maclay, James. 3 Woodlands Terrace, Glasgow.
1901. §Maclay, William. Thornwood, Langside, Glasgow.
1901. §McLean, Angus, B.Sc. Ascog, Meikleriggs, Paisley.
1892. *Maclean, Magnus, M.A., D.Sc., F.R.S.E. (Local Sec. 1901), Professor of Electrical Engineering, Technical College, Glasgow.
1884. ‡McLennan, Frank. 317 Drummond-street, Montreal, Canada.

Year of Election.

1884. ‡McLennan, Hugh. 317 Drummond-street, Montreal, Canada.
1884. ‡McLennan, John. Lancaster, Ontario, Canada.
1868. §McLeod, Herbert, F.R.S. (Pres. B, 1892; Council, 1885-90). 9 Coverdale Road, Richmond, Surrey.
1892. ‡Macleod, W. Bowman. 16 George-square, Edinburgh.
1883. *McMahon, Lieut.-General C. A., F.R.S., F.G.S. 20 Nevern-square, South Kensington, S.W.
1883. ‡MacMahon, Major Percy A., R.A., D.Sc., F.R.S. (Pres. A, 1901; Council, 1898-). Queen Anne's Mansions, Westminster, S.W.
1878. *M'Master, George, M.A., J.P. Rathmines, Ireland.
1884. ‡McMurrick, J. Playfair. University of Michigan, Ann Arbor, Michigan, U.S.A.
1867. ‡M'Neill, John. Balhousie House, Perth.
1878. ‡Macnie, George. 59 Bolton-street, Dublin.
1887. ‡Maconochie, A. W. Care of Messrs. Maconochie Bros., Lowestoft.
1883. ‡Macpherson, J. 44 Frederick-street, Edinburgh.
1901. §MacRitchie, David. 4 Archibald Place, Edinburgh.
*Macrory, Edmund, M.A., K.C. 19 Pembridge-square, W.
1887. ‡Macy, Jesse. Grinnell, Iowa, U.S.A.
1883. †Malden, W. H. Marlborough College, Wilts.
1883. †Maggs, Thomas Charles, F.G.S. 56 Clarendon-villas, West Brighton.
1868. ‡Magnay, F. A. Drayton, near Norwich.
1875. *Magnus, Sir Philip, B.Sc. 16 Gloucester-terrace, Hyde Park, W.
1896. †Maguire, Thomas Philip. Eastfield, Lodge-lane, Liverpool.
1878. ‡Mahony, W. A. 34 College-green, Dublin.
1887. ‡Mainprice, W. S. Longcroft, Altrincham, Cheshire.
1883. ‡Maitland, P. C. 136 Great Portland-street, W.
1899. ‡Makarius, Saleem. 'Al Mokattam,' Cairo.
1881. ‡Malcolm, Lieut.-Colonel, R.E. 72 Nunthorpe-road, York.
1874. ‡Malcolmson, A. B. Friends' Institute, Belfast.
1857. ‡Mallet, John William, Ph.D., M.D., F.R.S., F.C.S., Professor of Chemistry in the University of Virginia, Albemarle Co., U.S.A.
1896. *Manbré, Alexandre. 15 Alexandra-drive, Liverpool.
1897. ‡Mance, Sir H. C. 32 Earl's Court-square, S.W.
1887. ‡Manchester, The Right Rev. the Lord Bishop of, D.D. Bishop's Court, Manchester.
1870. ‡Manifold, W. H., M.D. 45 Rodney-street, Liverpool.
1901. §Mann, John, jun., M.A., 137 West George Street, Glasgow.
1888. ‡Mann, W. J. Rodney House, Trowbridge.
1894. ‡Manning, Percy, M.A., F.S.A. Watford, Herts.
1864. ‡Mansel-Pleydell, J. C., F.G.S. Whatcombe, Blandford, Dorset.
1888. ‡Mansergh, James, M.Inst.C.E., F.R.S., F.G.S. 5 Victoria-street, Westminster, S.W.
1891. ‡Manuel, James. 175 Newport-road, Cardiff.
1887. *March, Henry Colley, M.D., F.S.A. Portesham, Dorchester, Dorsetshire.
1870. ‡Marcoartu, His Excellency Don Arturo de. Madrid.
1898. *Mardon, Heber. 2 Litfield-place, Clifton, Bristol.
1900. §Margerison, Samuel. Calverley Lodge, near Leeds.
1887. ‡Margetson, J. Charles. The Rocks, Limpley, Stoke.
1883. ‡Marginson, James Fleetwood. The Mount, Fleetwood, Lancashire.
1887. ‡Markham, Christopher A., F.R.Met.Soc. Spratton, Northampton.
1864. ‡Markham, Sir Clements R., K.C.B., F.R.S., Pres.R.G.S., F.S.A. (Pres. E, 1879; Council 1893-96). 21 Eccleston-square, S.W.
1894. ‡*Markoff, Dr. Anatolius.* 44 *Museum-street, W.C.*
1863. ‡Marley, John. Mining Office, Darlington.

Year of
Election.
1888. ‡Marling, W. J. Stanley Park, Stroud, Gloucestershire.
1888. ‡Marling, Lady. Stanley Park, Stroud, Gloucestershire.
1881. *MARR, J. E., M.A., F.R.S., F.G.S. (Pres. C, 1896; Council 1896–). St. John's College, Cambridge.
1887. ‡Marsden, Benjamin. Westleigh, Heaton Mersey, Manchester.
1884. *Marsden, Samuel. 1015 North Leffingwell-avenue, St. Louis, Missouri, U.S.A.
1892. *Marsden-Smedley, J. B. Lea Green, Cromford, Derbyshire.
1883. *Marsh, Henry. 72 Wellington Street, Leeds.
1887. ‡Marsh, J. E., M.A. The Museum, Oxford.
1864. ‡Marsh, Thomas Edward Miller. 37 Grosvenor-place, Bath.
1889. *MARSHALL, ALFRED, M.A., LL.D. (Pres. F, 1890), Professor of Political Economy in the University of Cambridge. Balliol Croft, Madingley-road, Cambridge.
1892. §Marshall, Hugh, D.Sc., F.R.S.E. 131 Warrender Park-road, Edinburgh.
1890. ‡Marshall, John. Derwent Island, Keswick.
1901. §Marshall, Robert. 97 Wellington Street, Glasgow.
1886. *MARSHALL, WILLIAM BAYLEY, M.Inst.C.E. Richmond Hill, Edgbaston, Birmingham.
1849. *MARSHALL, WILLIAM P., M.Inst.C.E. Richmond Hill, Edgbaston, Birmingham.
1865. §MARTEN, EDWARD BINDON. Pedmore, near Stourbridge.
1899. §Martin, Miss A. M. Park View, 32 Bayham-road, Sevenoaks.
1891. *Martin, Edward P., J.P. Dowlais, Glamorgan.
1887. *Martin, Rev. H. A. Grosvenor Club, London, S.W.
1884. §Martin, N. H., J.P., F.L.S. Ravenswood, Low Fell, Gateshead-on-Tyne.
1889. *Martin, Thomas Henry, Assoc.M.Inst.C.E. Northdene, New Barnet, Herts.
1890. ‡Martindale, William, F.L.S. 19 Devonshire-street, Portland-place, W.
1865. ‡Martineau, R. F. 18 Highfield-road, Edgbaston, Birmingham.
1883. §MARWICK, Sir J. D., LL.D., F.R.S.E. (Local Sec. 1871, 1876, 1901), Glasgow.
1891. ‡Marychurch, J. G. 46 Park-street, Cardiff.
1873. *MASHAM, Lord. Swinton Park, Swinton.
1847. ‡MASKELYNE, NEVIL STORY, M.A., F.R.S., F.G.S. (Council 1874–80). Basset Down House, Swindon.
1886. ‡Mason, Hon. J. E. Fiji.
1879. ‡*Mason, James, M.D. Montgomery House, Sheffield.*
1896. ‡Mason, Philip B., F.L.S., F.Z.S. Burton-on-Trent.
1893. *Mason, Thomas. Endersleigh, Alexandra Park, Nottingham.
1891. *Massey, William H., M.Inst.C.E. Twyford, R.S.O., Berkshire.
1885. ‡Masson, Orme, D.Sc. University of Melbourne, Victoria, Australia.
1898. ‡Masterman, A. T. University of St. Andrews, N.B.
1901. *Mather, G. R. Boxlea, Wellingborough.
1883. ‡Mather, Robert V. Birkdale Lodge, Birkdale, Southport.
1887. *Mather, William, M.P., M.Inst.C.E. Salford Iron Works, Manchester.
1890. ‡Mathers, J. S. 1 Hanover-square, Leeds.
1865. ‡Mathews, C. E. Waterloo-street, Birmingham.
1898 ‡Mathews, E. R. Norris. Cotham-road, Cotham, Bristol.
1894. ‡MATHEWS, G. B., M.A., F.R.S. 10 Menai View, Bangor.
1865. *Mathews, G. S. 32 Augustus-road, Edgbaston, Birmingham.
1889. ‡Mathews, John Hitchcock. 1 Queen's-gardens, Hyde Park, W.
1881. ‡Mathwin, Henry, B.A. Bickerton House, Southport.
1883. ‡Mathwin, Mrs. 40 York-road, Birkdale, Southport.

Year of Election.

1858. ‡Matthews, F. C. Mandre Works, Driffield, Yorkshire.
1885. ‡Matthews, James. Springhill, Aberdeen.
1885. ‡Matthews, J. Duncan. Springhill, Aberdeen.
1899. ‡Matthews, William, C.M.G., M.Inst.C.E. 9 Victoria-street, S.W.
1893. ‡Mavor, Professor James, M.A., LL.D. University of Toronto, Canada.
1865. *Maw, George, F.L.S., F.G.S., F.S.A. Benthall, Kenley, Surrey.
1894. §Maxim, Sir Hiram S. 18 Queen's Gate-place, Kensington, S.W.
*Maxwell, Robert Perceval. Finnebrogue, Downpatrick.
1883. §May, William, F.G.S. Northfield, St. Mary Cray, Kent.
1901. §May, W. Page, M.D., B.Sc. 9 Manchester Square, W.
1883. ‡Mayall, George. Clairville, Birkdale, Southport.
1884. *Maybury, A. C., D.Sc. 19 Bloomsbury-square, W.C.
1878. *Mayne, Thomas. 33 Castle-street, Dublin.
1871. ‡Meikle, James, F.S.S. 6 St. Andrew's-square, Edinburgh.
1879. §Meiklejohn, John W. S., M.D. 105 Holland-road, W.
1887. ‡Meischke-Smith, W. Rivala Lumpore, Salengore, Straits Settlements.
1881. *Meldola, Raphael, F.R.S., F.R.A.S., F.C.S., F.I.C. (Pres. B, 1895; Council 1892–99), Professor of Chemistry in the Finsbury Technical College, City and Guilds of London Institute. 6 Brunswick-square, W.C.
1883. ‡Mellis, Rev. James. 23 Park-street, Southport.
1879. *Mellish, Henry. Hodsock Priory, Worksop.
1866. ‡Mello, Rev. J. M., M.A., F.G.S. Cliff Hill, Warwick.
1883. ‡Mello, Mrs. J. M. Cliff Hill, Warwick.
1896. §Mellor, G. H. Weston, Blundellsands, Liverpool.
1881. §Melrose, James. Clifton Croft, York.
1887. ‡Melvill, J. Cosmo, M.A. Kersal Cottage, Prestwich, Manchester.
1863. ‡Melvin, Alexander. 42 Buccleuch-place, Edinburgh.
1896. ‡Menneer, R. R. Care of Messrs. Grindlay & Co., Parliament-street, S.W.
1901. §Mennell, F. P. 8 Addison Road, W.
1862. ‡Mennell, Henry T. St. Dunstan's-buildings, Great Tower-street, E.C.
1879. ‡Merivale, John Herman, M.A. (Local Sec. 1889). Togston Hall, Acklington.
1899. *Merrett, William H. Hetherley, Grosvenor Road, Wallington, Surrey.
1880. ‡Merry, Alfred S. Bryn Heulog, Sketty, near Swansea.
1899. §Merryweather, J. C. 4 Whitehall-court, S.W.
1889. *Merz, John Theodore. The Quarries, Newcastle-upon-Tyne.
1863. ‡Messent, P. T. 4 Northumberland-terrace, Tynemouth.
1896. §Metzler, W. H., Professor of Mathematics in Syracuse University, Syracuse, New York, U.S.A.
1869. ‡Miall, Louis C., F.R.S., F.L.S., F.G.S. (Pres. D, 1897; Local Sec. 1890), Professor of Biology in the Yorkshire College, Leeds.
1886. ‡Middlemore, Thomas. Holloway Head, Birmingham.
1865. ‡Middlemore, William. Edgbaston, Birmingham.
1881. *Middlesbrough, The Right Rev. Richard Lacy, D.D., Bishop of Middlesbrough.
1893. §Middleton, A. 25 Lister-gate, Nottingham.
1881. ‡Middleton, R. Morton, F.L.S., F.Z.S. 46 Windsor-road, Ealing, W.
1894. *Miers, H. A., M.A., F.R.S., F.G.S., Professor of Mineralogy in the University of Oxford. Magdalen College, Oxford.
1889. ‡Milburn, John D. Queen-street, Newcastle-upon-Tyne.
1885. ‡Miles, Charles Albert. Buenos Ayres.

Year of Election.

1881. ‡MILES, MORRIS (Local Sec. 1882). Warbourne, Hill-lane, Southampton.
1885. §MILL, HUGH ROBERT, D.Sc., LL.D., F.R.S.E., F.R.G.S. (Pres. E, 1901). 22 Gloucester-place, Portman-square, W.
1889. *Millar, Robert Cockburn. 30 York-place, Edinburgh.
• Millar, Thomas, M.A., LL.D., F.R.S.E. Perth.
1875. ‡*Miller, George. Brentry, near Bristol.*
1895. ‡Miller, Henry, M.Inst.C.E. Bosmere House, Norwich-road, Ipswich.
1888. ‡Miller, J. Bruce. Rubislaw Den North, Aberdeen.
1885. ‡Miller, John. 9 Rubislaw-terrace, Aberdeen.
1886. ‡Miller, Rev. John, B.D. The College, Weymouth.
1861. *Miller, Robert. Totteridge House, Hertfordshire, N.
1895. §Miller, Thomas, M.Inst.C.E. 9 Thoroughfare, Ipswich.
1884. ‡Miller, T. F., B.Ap.Sc. Napanee, Ontario, Canada.
1876. ‡Miller, Thomas Paterson. Cairns, Cambuslang, N.B.
1897. ‡Miller, Willet G., Professor of Geology in Queen's University, Kingston, Ontario, Canada.
1868. *MILLS, EDMUND J., D.Sc., F.R.S., F.C.S. 11 Greenhill Road, Harrow.
1880. ‡Mills, Mansfeldt H., M.Inst.C.E., F.G.S. Sherwood Hall, Mansfield.
1885. ‡Milne, Alexander D. 40 Albyn-place, Aberdeen.
1882. *MILNE, JOHN, F.R.S., F.G.S. Shide Hill House, Shide, Isle of Wight.
1885. ‡Milne, William. 40 Albyn-place, Aberdeen.
1898. *Milner, S. Roslington, B.Sc. University College, Sheffield.
1882. ‡Milnes, Alfred, M.A., F.S.S. 22A Goldhurst-terrace, South Hampstead, N.W.
1880. ‡MINCHIN, G. M., M.A., F.R.S., Professor of Mathematics in the Royal Indian Engineering College, Cooper's Hill, Surrey.
1855. ‡Mirrlees, James Buchanan. 45 Scotland-street, Glasgow.
1859. ‡Mitchell, Alexander, M.D. Old Rain, Aberdeen.
1901. *Mitchell, Andrew Acworth. 7 Huntly Gardens, Glasgow.
1883. ‡Mitchell, Charles T., M.A. 41 Addison-gardens North, Kensington, W.
1883. ‡Mitchell, Mrs. Charles T. 41 Addison-gardens North, Kensington, W.
1901. *Mitchell, G. A. 5 West Regent Street, Glasgow.
1885. ‡Mitchell, P. Chalmers. Christ Church, Oxford.
1895. *Moat, William, M.A. Johnson, Eccleshall, Staffordshire.
1885. ‡Moffat, William. 7 Queen's-gardens, Aberdeen.
1885. ‡Moir, James. 25 Carden-place, Aberdeen.
1883. ‡Mollison, W. L., M.A. Clare College, Cambridge.
1877. *Molloy, Right Rev. Gerald, D.D. 86 Stephen's-green, Dublin.
1884. ‡Monaghan, Patrick. Halifax (Box 317), Nova Scotia, Canada.
1900. §MONCKTON, H. W., V.P.G.S. 3 Harcourt Buildings, Temple, E.C.
1887. *MOND, LUDWIG, Ph.D., F.R.S., F.C.S. (Pres. B, 1896). 20 Avenue-road, Regent's Park, N.W.
1891. *Mond, Robert Ludwig, M.A., F.R.S.E., F.G.S. 20 Avenue-road, Regent's Park, N.W.
1882. *Montagu, Sir Samuel, Bart., M.P. 12 Kensington Palace-gardens, W.
1892. ‡Montgomery, Very Rev. J. F. 17 Athole-crescent, Edinburgh.
1872. ‡Montgomery, R. Mortimer. 3 Porchester-place, Edgware-road, W.
1872. ‡Moon, W., LL.D. 104 Queen's-road, Brighton.
1896. ‡Moore, A. W., M.A. Woodbourne House, Douglas, Isle of Man.
1894. §Moore, Harold E. 41 Bedford-row, W.C.
1890. ‡Moore, Major, R.E. School of Military Engineering, Chat
1901. *Moore, Robert J. 156 Vincent Street, Glasgow.

Year of Election.

1896. *Mordey, W. M. Prince's-mansions, Victoria-street, S.W.
1891. ‡Morel, P. Lavernock House, near Cardiff.
1901. §Moreno, Francisco P. Argentine Legation, W.
1881. ‡MORGAN, ALFRED. 50 West Bay-street, Jacksonville, Florida, U.S.A.
1895. ‡MORGAN, C. LLOYD, F.R.S., F.G.S., Principal of University College, Bristol. 16 Canynge-road, Clifton, Bristol.
1873. ‡Morgan, Edward Delmar, F.R.G.S. 15 Roland-gardens, South Kensington, S.W.
1891. ‡Morgan, F. Forest Lodge, Ruspidge, Gloucestershire.
1896. §Morgan, George. 21 Upper Parliament Street, Liverpool.
1887. ‡Morgan, John Gray. 38 Lloyd-street, Manchester.
1882. ‡Morgan, Thomas, J.P. Cross House, Southampton.
1901. *Morison, James. Perth.
1892. ‡Morison, John, M.D., F.G.S. Victoria-street, St. Albans.
1889. §Morison, J. Rutherford, M.D. 14 Saville-row, Newcastle-upon-Tyne.
1893. ‡Morland, John, J.P. Glastonbury.
1891. ‡Morley, H. The Gas Works, Cardiff.
1883. *MORLEY, HENRY FORSTER, M.A., D.Sc., F.C.S. 47 Broadhurst-gardens, South Hampstead, N.W.
1889. ‡MORLEY, The Right Hon. JOHN, M.A., LL.D., M.P., F.R.S. 95 Elm Park-gardens, S.W.
1896. ‡Morrell, R. S. Caius College, Cambridge.
1881. ‡Morrell, W. W. York City and County Bank, York.
1883. ‡Morris, C. S. Millbrook Iron Works, Landore, South Wales.
1892. ‡MORRIS, DANIEL, C.M.G., M.A., D.Sc., F.L.S. Barbados, West Indies.
1899. §Morris, G. Harris, B.Sc., Ph.D., F.I.C. Helenslea, South Hill Park, Bromley, Kent.
1883. ‡Morris, George Lockwood. Millbrook Iron Works, Swansea.
1880. §Morris, James. 6 Windsor-street, Uplands, Swansea.
1896. *Morris, J. T. 13 Somers-place, W.
1888. ‡Morris, J. W., F.L.S. 27 Green Park, Bath.
Morris, Samuel, M.R.D.S. Fortview, Clontarf, near Dublin.
1874. ‡Morrison, G. J., M.Inst.C.E. Shanghai, China.
1871. *Morrison, J. D. Fordel Castle, Glenfarg, Perthshire.
1899. §Morrow, Captain John, M.Sc. 7 Rockleaze-avenue, Sneyd Park, Bristol.
1865. ‡Mortimer, J. R. St. John's-villas, Driffield.
1869. ‡Mortimer, William. Bedford-circus, Exeter.
1858. *MORTON, HENRY JOSEPH. 2 Westbourne-villas, Scarborough.
1887. ‡Morton, Percy, M.A. Illtyd House, Brecon, South Wales.
1886. *Morton, P. F. 15 Ashley Place, Westminster, S.W.
1896. *MORTON, WILLIAM B., M.A., Professor of Natural Philosophy in Queen's College, Belfast.
1883. ‡Moseley, Mrs. Firwood, Clevedon, Somerset.
1878. *Moss, JOHN FRANCIS, F.R.G.S. (Local Sec. 1879). Beechwood, Brincliffe, Sheffield.
1876. §Moss, RICHARD JACKSON, F.I.C., M.R.I.A. Royal Dublin Society, and St. Aubyn's, Ballybrack, Co. Dublin.
1864. *Mosse, J. R. 5 Chiswick-place, Eastbourne.
1892. ‡Mossman, R. C., F.R.S.E. 10 Blacket-place, Edinburgh.
1873. ‡Mossman, William. St. Hilda's, Frizinghall, Bradford.
1892. *Mostyn, S. G., M.A. Fairycroft Terrace, Saffron Walden, Essex.
1866. ‡MOTT, FREDERICK T., F.R.G.S. Crescent House, Leicester.

Year of Election.

1856. ‡Mould, Rev. J. G., B.D. Roseland, Meadfoot, Torquay.
1878. *MOULTON, J. FLETCHER, M.A., K.C., M.P., F.R.S. 57 Onslow-square, S.W.
1863. ‡Mounsey, Edward. Sunderland.
1861. *Mountcastle, William Robert. The Wigwam, Ellenbrook, near Manchester.
1877. ‡MOUNT-EDGCUMBE, The Right Hon. the Earl of, D.C.L. Mount-Edgcumbe, Devonport.
1899. §Mowll, Martyn. Chaldercot, Leyburne-road, Dover.
1887. ‡Moxon, Thomas B. County Bank, Manchester.
1888. ‡Moyle, R. E., M.A., F.C.S. Heightley, Chudleigh, Devon.
1884. ‡Moyse, C. E., B.A., Professor of English Language and Literature in McGill College, Montreal. 802 Sherbrooke-street, Montreal, Canada.
1884. ‡Moyse, Charles E. 802 Sherbrooke-street, Montreal, Canada.
1899. *Muff, Herbert B. Aston Mount, Heaton, Bradford, Yorkshire.
1894. ‡Mugliston, Rev. J., M.A. Newick House, Cheltenham.
1876. *Muir, Sir John, Bart. Demster House, Perthshire.
1874. ‡MUIR, M. M. PATTISON, M.A. Gonville and Caius College, Cambridge.
1872. *MUIRHEAD, ALEXANDER, D.Sc., F.C.S. 2 Prince's-street, Storey's-gate, Westminster, S.W.
1876. *Muirhead, Robert Franklin, M.A., B.Sc. 24 Kersland-street, Hillhead, Glasgow.
1883. ‡Mulhall, Mrs. Marion. Fancourt, Balbriggan, Co. Dublin.
1884. *MÜLLER, HUGO, Ph.D., F.R.S., F.C.S. 13 Park-square East, Regent's Park, N.W.
1880. ‡Muller, Hugo M. 1 Grünanger-gasse, Vienna.
1897. ‡Mullins, W. E. Preshute House, Marlborough, Wilts.
1898. ‡Mumford, C. E. Bury St. Edmunds.
Munby, Arthur Joseph. 6 Fig-tree-court, Temple, E.C.
1901. *Munby, Alan E. Felstead, Essex.
1876. ‡Munro, Donald, M.D., F.C.S. The University, Glasgow.
1901. §Munro, Donald, M.D., J.P. Wheatholm, Pollokshaws, Glasgow.
1898. ‡Munro, John, Professor of Mechanical Engineering in the Merchant Venturers' Technical College, Bristol.
1883. *MUNRO, ROBERT, M.A., M.D. (Pres. H, 1893). 48 Manor-place, Edinburgh.
1855. ‡Murdoch, James Barclay. Capelrig, Mearns, Renfrewshire.
1890. ‡Murphy, A. J. Preston House, Leeds.
1889. ‡Murphy, James, M.A., M.D. Holly House, Sunderland.
1884. §Murphy, Patrick. Marcus-square, Newry, Ireland.
1887. ‡Murray, A. Hazeldean, Kersal, Manchester.
1891. ‡MURRAY, G. R. M., F.R.S., F.R.S.E., F.L.S. British Museum (Natural History), South Kensington, S.W.
1859. ‡Murray, John, M.D. Forres, Scotland.
1884. ‡MURRAY, Sir JOHN, K.C.B., LL.D., Ph.D., F.R.S., F.R.S.E. (Pres. E, 1899). Challenger Lodge, Wardie, Edinburgh.
1884. ‡Murray, J. Clark, LL.D., Professor of Logic and Mental and Moral Philosophy in McGill University, Montreal. 111 McKay-street, Montreal, Canada.
1872. ‡Murray, J. Jardine, F.R.C.S.E. 99 Montpellier-road, Brighton.
1892. ‡Murray, T. S. 1 Nelson-street, Dundee.
1863. ‡Murray, William, M.D. 9 Ellison-place, Newcastle-on-Tyne.
1874. §Musgrave, Sir James, Bart., D.L. Drumglass House, Belfast.
1897. ‡Musgrave, James, M.D. 511 Bloor-street West, Toronto, Canada.
1870. *Muspratt, Edward Knowles. Seaforth Hall, near Liverpool.

Year of Election.

1891. ‡Muybridge, Eadweard. University of Pennsylvania, Philadelphia, U.S.A.
1890. *MYRES, JOHN L., M.A., F.S.A. Christ Church, Oxford.

1886. ‡NAGEL, D. H., M.A. (Local Sec. 1894). Trinity College, Oxford.
1892. *Nairn, Michael B. Kirkcaldy, N.B.
1890. §Nalder, Francis Henry. 34 Queen-street, E.C.
1876. ‡Napier, James S. 9 Woodside-place, Glasgow.
1872. ‡NARES, Admiral Sir G. S., K.C.B., R.N., F.R.S., F.R.G.S. 11 Claremont-road, Surbiton.
1887. ‡Nason, Professor Henry B., Ph.D. Troy, New York, U.S.A.
1896. †Neal, James E., U.S. Consul. 26 Chapel-street, Liverpool.
1887. §Neild, Charles. 19 Chapel Walks, Manchester.
1883. *Neild, Theodore, B.A. The Vista, Leominster.
1887. †Neill, Robert, jun. Beech Mount, Higher Broughton, Manchester.
1855. ‡Neilson, Walter. 172 West George-street, Glasgow.
1897. ‡Nesbitt, Beattie S. A., M.D. 71 Grosvenor-street, Toronto, Canada.
1868. ‡Nevill, Rev. H. R. The Close, Norwich.
1898. §Nevill, Rev. J. H. N., M.A. The Vicarage, Stoke Gabriel, South Devon.
1866. *Nevill, The Right Rev. Samuel Tarratt, D.D., F.L.S., Bishop of Dunedin, New Zealand.
1889. ‡NEVILLE, F. H., M.A., F.R.S. Sidney College, Cambridge.
1869. ‡Nevins, John Birkbeck, M.D. 3 Abercromby-square, Liverpool.
1889. *Newall, H. Frank. Madingley Rise, Cambridge.
1901. §Newbigin, Miss Marion J. Greenhill House, Alnwick.
1886. ‡Newbolt, F. G. Oakley Lodge, Weybridge, Surrey.
1901. §Newman, F. H. Tullie House, Carlisle.
1889. §Newstead, A. H. L., B.A. 38 Green Street, Bethnal Green, N.E.
1860. *NEWTON, ALFRED, M.A., F.R.S., F.L.S. (Pres. D, 1887; Council 1875–82). Professor of Zoology and Comparative Anatomy in the University of Cambridge. Magdalene College, Cambridge.
1892. ‡NEWTON, E. T., F.R.S., F.G.S. Geological Museum, Jermyn-street, S.W.
1867. ‡Nicholl, Thomas. Dundee.
1866. ‡NICHOLSON, Sir CHARLES, Bart., M.D., D.C.L., LL.D., F.G.S., F.R.G.S. (Pres. E, 1866). The Grange, Totteridge, Herts.
1887. *Nicholson, John Carr. Moorfield House, Headingley, Leeds.
1884. ‡NICHOLSON, JOSEPH S., M.A., D.Sc. (Pres. F, 1893), Professor of Political Economy in the University of Edinburgh. Eden Lodge, Newbattle-terrace, Edinburgh.
1883. †Nicholson, Richard, J.P. Whinfield, Hesketh Park, Southport.
1887. ‡Nicholson, Robert H. Bourchier. 21 Albion-street, Hull.
1893. ‡Nickolls, John B., F.C.S. The Laboratory, Guernsey.
1887 ‡Nickson, William. Shelton, Sibson-road, Sale, Manchester.
1901. §NICOL, JAMES, City Chamberlain. Glasgow.
1885. ‡Nicol, W. W. J., D.Sc., F.R.S.E. 15 Blacket-place, Edinburgh.
1896. ‡Nisbet, J. Tawse. 175 Lodge-lane, Liverpool.
1878. ‡NIVEN, CHARLES, M.A., F.R.S., F.R.A.S., Professor of Natural Philosophy in the University of Aberdeen. 6 Chanonry, Old Aberdeen.
1877. ‡Niven, Professor James, M.A. King's College, Aberdeen.
1874. ‡Nixon, Randal C. J., M.A. Royal Academical Institution, Belfast.
1863. *NOBLE, Sir ANDREW, K.C.B., F.R.S., F.R.A.S., F.C.S. (Pres. G, 1890; Local Sec. 1863). Elswick Works, and Jesmond Dene House, Newcastle-upon-Tyne.

Year of Election.

1879. ‡Noble, T. S. Lendal, York.
1887. †Nodal, John H. The Grange, Heaton Moor, near Stockport.
1870. ‡Nolan, Joseph, M.R.I.A. 14 Hume-street, Dublin.
1863. §NORMAN, Rev. Canon ALFRED MERLE, M.A., D.C.L., LL.D., F.R.S., F.L.S. The Red House, Berkhamsted.
1888. ‡Norman, George. 12 Brock-street, Bath.
1865. ‡NORRIS, RICHARD, M.D. 2 Walsall-road, Birchfield, Birmingham.
1872. ‡Norris, Thomas George. Gorphwysfa, Llanrwst, North Wales.
1883. *Norris, William G. Dale House, Coalbrookdale, R.S.O., Shropshire.
NORTON, The Right Hon. Lord, K.C.M.G. 35 Eaton-place, S.W.; and Hamshall, Birmingham.
1886. ‡Norton, Lady. 35 Eaton-place, S.W.; and Hamshall, Birmingham.
1894. §NOTCUTT, S. A., LL.M., B.A., B.Sc. (Local Sec. 1895). 98 Anglesea Road, and Constitution Hill, Ipswich.
Nowell, John. Farnley Wood, near Huddersfield.
1896. ‡Nugent, the Right Rev. Monsignor. 18 Adelaide-terrace, Waterloo, Liverpool.
1887. ‡*Nursey, Perry Fairfax. 2 Trafalgar-buildings, Northumberland-avenue, London, W.C.*

1898. *O'Brien, Neville Forth. Queen Anne's-mansions, S.W.
1878. ‡O'Conor Don, The. Clonalis, Castlerea, Ireland.
1883. ‡Odgers, William Blake, M.A., LL.D. 4 Elm-court, Temple, E.C.
1858. *ODLING, WILLIAM, M.B., F.R.S., V.P.C.S. (Pres. B, 1864; Council 1865–70), Waynflete Professor of Chemistry in the University of Oxford. 15 Norham-gardens, Oxford.
1884. ‡Odlum, Edward, M.A. Pembroke, Ontario, Canada.
1857. ‡O'Donnavan, William John. 54 Kenilworth-square, Rathgar, Dublin.
1894. §Ogden, James. Kilner Deyne, Rochdale.
1896. ‡Ogden, Thomas. 4 Prince's-avenue, Liverpool.
1885. ‡Ogilvie, Alexander, LL.D. Gordon's College, Aberdeen.
1876. ‡Ogilvie, Campbell P. Sizewell House, Leiston, Suffolk.
1885. ‡OGILVIE, F. GRANT, M.A., B.Sc., F.R.S.E. (Local Sec. 1892). Heriot Watt College, Edinburgh.
1859. ‡Ogilvy, Rev. C. W. Norman. Baldan House, Dundee.
*Ogle, William, M.D., M.A. The Elms, Derby.
1884. ‡O'Halloran, J. S., C.M.G. Royal Colonial Institute, Northumberland-avenue, W.C.
1881. ‡Oldfield, Joseph. Lendal, York.
1887. ‡*Oldham, Charles. Romiley, Cheshire.*
1896. †Oldham, G. S. Town Hall, Birkenhead.
1892. ‡OLDHAM, H. YULE, M.A., F.R.G.S., Lecturer in Geography in the University of Cambridge. King's College, Cambridge.
1853. †OLDHAM, JAMES, M.Inst.C.E. Cottingham, near Hull.
1885. ‡Oldham, John. River Plate Telegraph Company, Monte Video.
1893. *OLDHAM, R. D., F.G.S., Geological Survey of India. Care of Messrs. H. S. King & Co., Cornhill, E.C.
1892. ‡*Oliphant, James. 50 Palmerston-place, Edinburgh.*
1863. ‡OLIVER, DANIEL, LL.D., F.R.S., F.L.S., Emeritus Professor of Botany in University College, London. 10 Kew Gardens-road, Kew, Surrey.
1887. ‡OLIVER, F. W., D.Sc., F.L.S., Professor of Botany in University College, London. 2 The Vale, Chelsea, S.W.
1883. §Oliver, Samuel A. Bellingham House, Wigan, Lancashire.
1889. §Oliver, Professor T., M.D. 7 Ellison-place, Newcastle-upon-Tyne.

Year of Election.

1882. §Olsen, O. T., F.L.S., F.R.G.S. 116 St. Andrew's-terrace, Grimsby.
1860. *OMMANNEY, Admiral Sir ERASMUS, C.B., LL.D., F.R.S., F.R.A.S., F.R.G.S. (Pres. E, 1877; Council 1873–80, 1884–90). 29 Connaught-square, Hyde Park, W.
1880. *Ommanney, Rev. E. A. St. Michael's and All Angels, Portsea, Hants.
1872. ‡Onslow, D. Robert. New University Club, St. James's, S.W.
1883. ‡Oppert, Gustav, Professor of Sanskrit in the University of Berlin.
1899. ‡Orling, Axel. Moorgate Station-chambers, E.C.
1858. ‡Ormerod, T. T. Brighouse, near Halifax.
1883. ‡*Orpen, Miss. 58 Stephen's-green, Dublin.*
1884. *Orpen, Lieut.-Colonel R. T., R.E. Monksgrange, Enniscorthy, Co. Wexford.
1884. *Orpen, Rev. T. H., M.A. Binnbrooke, Cambridge.
1838. Orr, Alexander Smith. 57 Upper Sackville-street, Dublin.
1901. §Orr, Alexander Stewart. Care of Maitland, Price & Co., Mazagon, Bombay, India.
1899. ‡Osborn, Dr. F. A. The Châlet, Dover.
1897. ‡Osborne, James K. 40 St. Joseph-street, Toronto, Canada.
1901. §Osborne, W. A., D.Sc. University College, W.C.
1887. §O'Shea, L. T., B.Sc. University College, Sheffield.
*OSLER, A. FOLLETT, F.R.S. South Bank, Edgbaston, Birmingham.
1897. ‡Osler, E. B., M.P. Rosedale, Toronto, Canada.
1865. *Osler, Henry F. Coppy Hill, Linthurst, near Bromsgrove, Birmingham.
1884. ‡OSLER, Professor WILLIAM, M.D., F.R.S. Johns Hopkins University, Baltimore, U.S.A.
1884. ‡O'Sullivan, James, F.C.S. 71 Spring Terrace-road, Burton-on-Trent.
1882. *Oswald, T. R. Castle Hall, Milford Haven.
1881. *Ottewell, Alfred D. 14 Mill Hill-road, Derby.
1896. ‡Oulton, W. Hillside, Gateacre, Liverpool.
1882. ‡Owen, Rev. C. M., M.A. St. George's, Edgbaston, Birmingham.
1889. *Owen, Alderman H. C. Compton, Wolverhampton.
1896. §Owen, Peter. The Elms, Capenhurst, Chester, and 2 Dale Street, Liverpool.

1889. ‡Page, Dr. F. 1 Saville-place, Newcastle-upon-Tyne.
1883. ‡Page, George W. Fakenham, Norfolk.
1883. ‡Page, Joseph Edward. 12 Saunders-street, Southport.
1894. ‡Paget, Octavius. 158 Fenchurch-street, E.C.
1898. ‡Paget, The Right Hon. Sir R. H., Bart. Cranmore Hall, Shepton Mallet.
1884. ‡Paine, Cyrus F. Rochester, New York, U.S.A.
1875. ‡Paine, William Henry, M.D. Stroud, Gloucestershire.
1870. *PALGRAVE, ROBERT HARRY INGLIS, F.R.S., F.S.S. (Pres. F, 1883). Belton, Great Yarmouth.
1896. ‡Pallis, Alexander. Tatoi, Aigburth-drive, Liverpool.
1889. ‡PALMER, Sir CHARLES MARK, Bart., M.P. Grinkle Park, Yorkshire.
1878. *Palmer, Joseph Edward. Rose Lawn, Ballybrack, Co. Dublin.
1866. §Palmer, William. Waverley House, Waverley-street, Nottingham.
1872. *Palmer, W. R. 49 Tierney-road, Streatham Hill, S.W.
1883. ‡*Pant, F. J. Van der. Clifton Lodge, Kingston-on-Thames.*
1886. ‡Paton, George A., F.R.S.E. 73 Westfield-road, Edgbaston, Birmingham.
1883. ‡Park, Henry. Wigan.

Year of Election.

1883. ‡Park, Mrs. Wigan.
1880. *Parke, George Henry, F.L.S., F.G.S. St. John's, Wakefield, Yorkshire.
1898. ‡Parker, G., M.D. 14 Pembroke-road, Clifton, Bristol.
1863. ‡Parker, Henry. Low Elswick, Newcastle-upon-Tyne.
1886. ‡Parker, Lawley. Chad Lodge, Edgbaston, Birmingham.
1899. ‡Parker, Mark. 30 Upper Fant-road, Maidstone.
1891. ‡PARKER, WILLIAM NEWTON, Ph.D., F.Z.S., Professor of Biology in University College, Cardiff.
1899. *Parkin, John. Blaithwaite, Carlisle.
1879. *Parkin, William. The Mount, Sheffield.
1887. ‡Parkinson, James. Greystones, Langho, Blackburn.
1859. ‡Parkinson, Robert, Ph.D. Yewbarrow House, Grange-over-Sands.
1883. ‡Parson, T. Cooke, M.R.C.S. Atherston House, Clifton, Bristol.
1878. ‡PARSONS, Hon. C. A., F.R.S., M.Inst.C.E. Holeyn Hall, Wylam-on-Tyne.
1898. *Partridge, Miss Josephine M. Girton College, Cambridge.
1898. ‡Pass, Alfred C. Clifton Down, Bristol.
1881. ‡Patchitt, Edward Cheshire. 128 Derby-road, Nottingham.
1887. ‡PATERSON, A. M., M.D., Professor of Anatomy in University College, Liverpool.
1897. ‡Paterson, John A. 23 Walmer-road, Toronto, Canada.
1896. ‡Paton, A. A. Greenbank-drive, Wavertree, Liverpool.
1897. ‡PATON, D. NOËL, M.D. 33 George-square, Edinburgh.
1883. *Paton, Rev. Henry, M.A. 120 Polwarth Terrace, Edinburgh.
1884. *Paton, Hugh. Box 2400, Montreal, Canada.
1871. **Patterson, A. Henry.* 16 *Ashburn-place, S.W.*
1876. ‡Patterson, T. L. Maybank, Greenock.
1874. ‡Patterson, W. H., M.R.I.A. 26 High-street, Belfast.
1863. ‡PATTINSON, JOHN, F.C.S. 75 The Side, Newcastle-upon-Tyne.
1879. *Patzer, F. R. Clayton Lodge, Newcastle, Staffordshire.
1863. ‡*Paul, Benjamin H., Ph.D.* 1 *Victoria-street, Westminster, S.W.*
1883. ‡Paul, George. 10 St. Mary's Avenue, Harrogate.
1892. ‡Paul, J. Balfour. 30 Heriot-row, Edinburgh.
1863. ‡PAVY, FREDERICK WILLIAM, M.D., F.R.S. 35 Grosvenor-street, W.
1887. *Paxman, James. Stisted Hall, near Braintree, Essex.
1887. *Payne, Miss Edith Annie. Hatchlands, Cuckfield, Hayward's Heath.
1881. ‡Payne, J. Buxton. 15 Mosley-street, Newcastle-upon-Tyne.
1877. *Payne, J. C. Charles. 1 Botanic-avenue, The Plains, Belfast.
1881. ‡Payne, Mrs. 1 Botanic-avenue, The Plains, Belfast.
1866. ‡Payne, Joseph F., M.D. 78 Wimpole-street, W.
1888. *Paynter, J. B. Hendford Manor House, Yeovil.
1886. ‡Payton, Henry. Wellington-road, Birmingham.
1876. ‡Peace, G. H. Monton Grange, Eccles, near Manchester.
1879. ‡Peace, William K. Moor Lodge, Sheffield.
1885. ‡PEACH, B. N., F.R.S., F.R.S.E., F.G.S. Geological Survey Office, Edinburgh.
1875. ‡Peacock, Thomas Francis. 12 South-square, Gray's Inn, W.C.
1886. *Pearce, Mrs. Horace. Orsett House, Birmingham Road, Kidderminster.
1884. ‡Pearce, William. Winnipeg, Canada.
1886. ‡Pearsall, Howard D. 19 Willow-road, Hampstead, N.W.
1883. ‡Pearson, Arthur A. Colonial Office, S.W.
1891. ‡Pearson, B. Dowlais Hotel, Cardiff.
1893. *Pearson, Charles E. Hillcrest, Lowdham, Nottinghamshire.
1898. §Pearson, George. Bank Chambers, Baldwin-street, Bristol.
1883. ‡Pearson, Miss Helen E. Oakhurst, Birkdale, Southport.

Year of Election.

1881. ‡Pearson, John. Glentworth House, The Mount, York.
1888. ‡Pearson, Mrs. Glentworth House, The Mount, York.
1872. **Pearson, Joseph.* *Grove Farm, Merlin, Raleigh, Ontario, Canada.*
1892. ‡Pearson, J. M. John Dickie-street, Kilmarnock.
1881. ‡Pearson, Richard. 57 Bootham, York.
1889. ‡Pease, Howard. Enfield Lodge, Benwell, Newcastle-upon-Tyne.
1863. ‡Pease, Sir Joseph W., Bart., M.P. Hutton Hall, near Guisborough.
Peckitt, Henry. Carlton Husthwaite, Thirsk, Yorkshire.
1855. *Peckover, Alexander, LL.D., F.S.A., F.L.S., F.R.G.S. Bank House, Wisbech, Cambridgeshire.
1888. ‡Peckover, Miss Alexandrina. Bank House, Wisbech, Cambridgeshire.
1885. ‡Peddie, William, D.Sc., F.R.S.E. 2 Cameron-park, Edinburgh.
1884. ‡Peebles, W. E. 9 North Frederick-street, Dublin.
1878. *Peek, William. The Manor House, Kemp Town, Brighton.
1901. *Peel, Hon. William, M.P. 13 King's Bench Walk, Temple, E.C.
1881. ‡Peggs, J. Wallace. 21 Queen Anne's-gate, S.W.
1878. ‡Pemberton, Charles Seaton. 44 Lincoln's Inn-fields, W.C.
1887. §Pendlebury, William H., M.A., F.C.S. (Local Sec. 1899). 6 Gladstone-terrace, Priory Hill, Dover.
1894. §Pengelly, Miss. Lamorna, Torquay.
1894. §Pengelly, Miss Hester. Lamorna, Torquay.
1897. ‡Penhallow, Professor D. P., M.A. McGill University, Montreal, Canada.
1896. ‡Pennant, P. P. Nantlys, St. Asaph.
1898. ‡Pentecost, Harold, B.A. Clifton College, Bristol.
1875. ‡Perceval, Rev. Canon John, M.A., LL.D. Rugby.
1889. ‡Percival, Archibald Stanley, M.A., M.B. 16 Ellison-place, Newcastle-upon-Tyne.
1898. ‡Percival, Francis W., M.A., F.R.G.S. 2 Southwick-place, W.
1895. ‡Percival, John, M.A., Professor of Botany in the South-Eastern Agricultural College, Wye, Kent.
*Perigal, Frederick. Lower Kingswood, Reigate.
1894. ‡Perkin, A. G., F.R.S.E., F.C.S., F.I.C. 8 Montpelier-terrace, Hyde Park, Leeds.
1868. *Perkin, William Henry, Ph.D., LL.D., F.R.S., V.P.C.S. (Pres. B, 1876; Council 1880–86). The Chestnuts, Sudbury, Harrow, Middlesex.
1884. ‡Perkin, William Henry, jun., LL.D., Ph.D., F.R.S., F.R.S.E. (Pres. B, 1900; Council 1901–). Professor of Organic Chemistry in the Owens College, Manchester. Fairview, Wilbraham-road, Fallowfield, Manchester.
1864. *Perkins, V. R. Wotton-under-Edge, Gloucestershire.
1898. *Perman, E. P. University College, Cardiff.
1885. ‡Perrin, Miss Emily. 31 St John's Wood Park, N.W.
1886. ‡Perrin, Henry S. 31 St. John's Wood Park, N.W.
1886. ‡Perrin, Mrs. 31 St. John's Wood Park, N.W.
1874. *Perry, John, M.E., D.Sc., F.R.S. (Council 1901–). Professor of Mechanics and Mathematics in the Royal College of Science, S.W.
1883. ‡Perry, Ottley L., F.R.G.S. Bolton-le-Moors, Lancashire.
1883. ‡Perry, Russell R. 34 Duke-street, Brighton.
1900. §Petavel, J. E. The Owens College, Manchester.
1897. ‡Peters, Dr. George A. 171 College-street, Toronto, Canada.
1898. ‡Pethick, William. Woodside, Stoke Bishop, Bristol.
1901. §Pethybridge, G. H. Museum of Science and Art, Dublin.
1883. ‡Petrie, Miss Isabella. Stone Hill, Rochdale.

Year of Election.

1895. ‡PETRIE, W. M. FLINDERS, D.C.L. (Pres. H, 1895), Professor of Egyptology in University College, W.C.
1871. *Peyton, John E. H., F.R.A.S., F.G.S. 13 Fourth-avenue, Hove, Brighton.
1886. ‡Phelps, Major-General A. 23 Augustus-road, Edgbaston, Birmingham.
1863. *PHENÉ, JOHN SAMUEL, LL.D., F.S.A., F.G.S., F.R.G.S. 5 Carlton-terrace, Oakley-street, S.W.
1896. ‡Philip, George, jun. Weldon, Bidston, Cheshire.
1892. ‡Philip, R. W., M.D. 4 Melville-crescent, Edinburgh.
1870. ‡Philip, T. D. 51 South Castle-street, Liverpool.
1853. *Philips, Rev. Edward. Hollington, Uttoxeter, Staffordshire.
1853. *Philips, Herbert. The Oak House, Macclesfield.
1877. §Philips, T. Wishart. Elizabeth Lodge, George-lane, Woodford, Essex.
1863. ‡Philipson, Sir G. H. 7 Eldon-square, Newcastle-upon-Tyne.
1883. ‡Phillips, Arthur G. 20 Canning-street, Liverpool.
1899. ‡Phillips, Charles E. S. Castle House, Shooter's Hill, Kent.
1894. §Phillips, Staff-Commander E. C. D., R.N., F.R.G.S. 14 Hargreaves-buildings, Chapel-street, Liverpool.
1887. ‡Phillips, H. Harcourt, F.C.S. 183 Moss-lane East, Manchester.
1890. §Phillips, R. W., M.A., D.Sc., Professor of Biology in University College, Bangor.
1883. ‡Phillips, S. Rees. Wonford House, Exeter.
1881. ‡Phillips, William. 9 Bootham-terrace, York.
1898. ‡Philps, Captain Lambe. 7 Royal-terrace, Weston-super-Mare.
1884. *Pickard, Rev. H. Adair, M.A. Airedale, Oxford.
1883. *Pickard, Joseph William. Oatlands, Lancaster.
1901. §Pickard, Robert H., D.Sc. Isca, Merlin Road, Blackburn.
1894. ‡PICKARD-CAMBRIDGE, Rev. O., M.A., F.R.S. Bloxworth Rectory, Wareham.
1885. *PICKERING, SPENCER P. U., M.A., F.R.S. Harpenden, Herts.
1884. *Pickett, Thomas E., M.D. Maysville, Mason Co., Kentucky, U.S.A.
1888. *Pidgeon, W. R. 42 Porchester-square, W.
1871. ‡Pigot, Thomas F., M.R.I.A. Royal College of Science, Dublin.
1884. ‡Pike, L. G., M.A., F.Z.S. 12 King's Bench-walk, Temple, E.C.
1865. ‡PIKE, L. OWEN. 4A Marlborough-gate, Hyde Park, W.
1873. ‡Pike, W. H., M.A., Ph.D. Toronto, Canada.
1896. *Pilkington, A. C. The Hazels, Prescot, Lancashire.
1896. *Pilling, William. Rosario, Heene-road, West Worthing.
1877. ‡Pim, Joseph T. Greenbank, Monkstown, Co. Dublin.
1868. ‡Pinder, T. R. St. Andrew's, Norwich.
1876. ‡PIRIE, Rev. G., M.A. (Local Sec. 1885), Professor of Mathematics in the University of Aberdeen. 33 College Bounds, Old Aberdeen.
1887. ‡Pitkin, James. 56 Red Lion-street, Clerkenwell, E.C.
1875. ‡Pitman, John. Redcliff Hill, Bristol.
1883. ‡Pitt, George Newton, M.A., M.D. 24 St. Thomas-street, Borough, S.E.
1864. ‡*Pitt, R. 5 Widcomb-terrace, Bath.*
1883. ‡Pitt, Sydney. 16 St. Andrew's-street, Holborn-circus, E.C.
1893. *PITT, WALTER, M.Inst.C.E. South Stoke House, near Bath.
1900. *Platts, Walter. Fairmount, Bingley.
1884. *Playfair, W. S., M.D., LL.D., Professor of Midwifery in King's College, London. 38 Grosvenor-street, W.
1898. ‡Playne, H. C. 28 College-road, Clifton, Bristol.
1893. ‡Plowright, Henry J. Brampton Foundries, Chesterfield.
1897. ‡Plummer, J. H. Bank of Commerce, Toronto, Canada.

Year of Election.

1898. §Plummer, W. E., M.A., F.R.A.S. The Observatory, Bidston, Birkenhead.
1899. ‡Plumptre, Fitzwalter. Goodnestone, Dover.
1857. ‡Plunkett, Thomas. Ballybrophy House, Borris-in-Ossory, Queen's Co., Ireland.
1900. *Pocklington, H. Cabourn. 41 Virginia Road, Leeds.
1881. §Pocklington, Henry. 20 Park-row, Leeds.
1888. ‡Pocock, Rev. Francis. 4 Brunswick-place, Bath.
1896. ‡Pollard, James. High Down, Hitchin, Herts.
1898. ‡Pollen, Rev. G. C. H., F.G.S. Ancienne Abbaye, Tronchiennes, Ghent, Belgium.
1896. *Pollex, Albert. Tenby House, Egerton Park, Rock Ferry.
1862. *Polwhele, Thomas Roxburgh, M.A., F.G.S. Polwhele, Truro, Cornwall.
1891. ‡Pomeroy, Captain Ralph. 201 Newport-road, Cardiff.
1900. §Pope, W. J. 48 Cawdor Road, Fallowfield, Manchester.
1892. ‡Popplewell, W. C., M.Sc., Assoc.M.Inst.C.E. The Yew, Marple, near Stockport.
1868. ‡Portal, Sir Wyndham S., Bart. Malshanger, Basingstoke.
1901. §Porter, Alfred W. 81 Parliament Hill Mansions, Lissenden Gardens, N.W.
1883. *Porter, Rev. C. T., LL.D., D.D. All Saints' Vicarage, Southport.
1883. ‡Postgate, Professor J. P., M.A. University College, Gower Street, W.C.
1887. ‡Potter, Edmund P. Hollinhurst, Bolton.
1883. ‡Potter, M. C., M.A., F.L.S., Professor of Botany in the College of Science, Newcastle-upon-Tyne. 14 Highbury, Newcastle-upon-Tyne.
1886. *Poulton, Edward B., M.A., F.R.S., F.L.S., F.G.S., F.Z.S. (Pres. D, 1896; Council 1895–1901). Professor of Zoology in the University of Oxford. Wykeham House, Banbury-road, Oxford.
1898. *Poulton, Edward Palmer. Wykeham House, Banbury-road, Oxford.
1873. *Powell, Sir Francis S., Bart., M.P., F.R.G.S. Horton Old Hall, Yorkshire; and 1 Cambridge-square, W.
1887. *Powell, Horatio Gibbs. Wood Villa, Tettenhall Wood, Wolverhampton.
1883. ‡Powell, John. Brynmill-crescent, Swansea.
1894. *Powell, Sir Richard Douglas, Bart., M.D. 62 Wimpole Street, Cavendish Square, W.
1875. ‡Powell, William Augustus Frederick. Norland House, Clifton, Bristol.
1887. §Pownall, George H. Manchester and Salford Bank, St. Ann-street, Manchester.
1867. ‡Powrie, James. Reswallie, Forfar.
1883. ‡Poynting, J. H., D.Sc., F.R.S. (Pres. A, 1899). Professor of Physics in the University, Birmingham.
1884. *Prankerd, A. A., D.C.L. 66 Banbury-road, Oxford.
1869. *Preece, Sir William Henry, K.C.B., F.R.S., M.Inst.C.E. (Pres. G, 1888; Council 1888–95, 1896–). Gothic Lodge, Wimbledon Common, Surrey; and 13 Queen Anne's Gate, S.W.
1888. *Preece, W. Llewellyn. Bryn Helen, Woodborough Road, Putney, S.W.
1892. §Prentice, Thomas. Willow Park, Greenock.
1889. §Preston, Alfred Eley, M.Inst.C.E., F.G.S. 14 The Exchange, Bradford, Yorkshire.
1894. ‡Preston, Arthur E. Piccadilly, Abingdon, Berkshire.
1893. *Preston, Martin Inett. 48 Ropewalk, Nottingham.

Year of
Election.

1884. *Prevost, Major L. de T., 2nd Battalion Argyll and Sutherland Highlanders.
Price, J. T. Neath Abbey, Glamorganshire.
1888. ‡PRICE, L. L. F. R., M.A., F.S.S. (Pres. F, 1895; Council, 1898–). Oriel College, Oxford.
1875. *Price, Rees. 163 Bath-street, Glasgow.
1891. ‡Price, William. 40 Park-place, Cardiff.
1897. *Price, W. A., M.A. The Mill House, Broomfield, Chelmsford.
1897. ‡Primrose, Dr. Alexander. 196 Simcoe-street, Toronto, Canada.
1892. ‡Prince, Professor Edward E., B.A. Ottawa, Canada.
1864. *Prior, R. C. A., M.D. 48 York-terrace, Regent's Park, N.W.
1889. *Pritchard, Eric Law, M.D., M.R.C.S. 70 Fairhazel Gardens, South Hampstead, N.W.
1876. *PRITCHARD, URBAN, M.D., F.R.C.S. 26 Wimpole-street, W.
1888. ‡Probyn, Leslie C. Onslow-square, S.W.
1881. §Procter, John William. Ashcroft, York.
1863. ‡Proctor, R. S. Grey-street, Newcastle-upon-Tyne.
Proctor, William. Elmhurst, Higher Erith-road, Torquay.
1884. *Proudfoot, Alexander, M.D. 100 State Street, Chicago, U.S.A.
1879. *Prouse, Oswald Milton, F.G.S. Alvington, Ilfracombe.
1872. *Pryor, M. Robert. Weston Park, Stevenage, Herts.
1871. *Puckle, Rev. T. J. Chestnut House, Huntingdon-road, Cambridge.
1873. ‡Pullan, Lawrence. Bridge of Allan, N.B.
1867. *Pullar, Sir Robert, F.R.S.E. Tayside, Perth.
1883. *Pullar, Rufus D., F.C.S. Brahan, Perth.
1891. ‡Pullen, W. W. F. University College, Cardiff.
1842. *Pumphrey, Charles. Castlewood, Park-road, Moseley, Birmingham.
1887. §PUMPHREY, WILLIAM (Local Sec. 1888). 2 Oakland-road, Redland, Bristol.
1885. ‡PURDIE, THOMAS, B.Sc., Ph.D., F.R.S., Professor of Chemistry in the University of St. Andrews. 14 South-street, St. Andrews, N.B.
1852. ‡Purdon, Thomas Henry, M.D. Belfast.
1881. ‡Purey-Cust, Very Rev. Arthur Percival, M.A., Dean of York. The Deanery, York.
1874. ‡PURSER, FREDERICK, M.A. Rathmines, Dublin.
1866. ‡PURSER, Professor JOHN, M.A., M.R.I.A. Queen's College, Belfast.
1878. ‡Purser, John Mallet. 3 Wilton-terrace, Dublin.
1884. *Purves, W. Laidlaw. 20 Stratford-place, Oxford-street, W.
1860. *Pusey, S. E. B. Bouverie. Pusey House, Faringdon.
1898. *Pye, Miss E. St. Mary's Hall, Rochester.
1883. §Pye-Smith, Arnold. Willesley, Park Hill Rise, Croydon.
1883. §Pye-Smith, Mrs. Willesley, Park Hill Rise, Croydon.
1868. ‡PYE-SMITH, P. H., M.D., F.R.S. 48 Brook-street, W.; and Guy's Hospital, S.E.
1879. ‡Pye-Smith, R. J. 350 Glossop-road, Sheffield.

1893. ‡Quick, James. University College, Bristol.
1894. ‡Quick, Professor W. J. University of Missouri, Columbia, U.S.A.

1870. ‡Rabbits, W. T. 6 Cadogan-gardens, S.W.
1870. ‡Radcliffe, D. R. Phœnix Safe Works, Windsor, Liverpool.
1896. §Radcliffe, Herbert. Balderstone Hall, Rochdale.
1855. *Radstock, The Right Hon. Lord. Mayfield, Woolston, Southampton.
1887. *Ragdale, John Rowland. The Beeches, Strand, near Manchester.
1864. ‡Rainey, James T. 3 Kent-gardens, Ealing, W.

Year of Election.

1898. *Raisin, Miss Catherine A., D.Sc. Bedford College, York-place, Baker-street, W.
1896. *RAMAGE, HUGH. St. John's College, Cambridge.
1894. *RAMBAUT, ARTHUR A., M.A., D.Sc., F.R.S., F.R.A.S., M.R.I.A. Radcliffe Observatory, Oxford.
1863. ‡RAMSAY, ALEXANDER. 2 Cowper-road, Acton, Middlesex, W.
1884. ‡Ramsay, George G., LL.D., Professor of Humanity in the University of Glasgow. 6 The College, Glasgow.
1884. ‡Ramsay, Mrs. G. G. 6 The College, Glasgow.
1861. †Ramsay, John. Kildalton, Argyllshire.
1885. ‡Ramsay, Major. Straloch, N.B.
1889. ‡Ramsay, Major R. G. W. Bonnyrigg, Edinburgh.
1876. *RAMSAY, WILLIAM, Ph.D., F.R.S. (Pres. B, 1897; Council 1891–98), Professor of Chemistry in University College, London. 12 Arundel-gardens, W.
1883. ‡Ramsay, Mrs. 12 Arundel-gardens, W.
1869. *Rance, H. W. Henniker, LL.D. 10 Castletown-road, West Kensington, W.
1901. §Rankin, James, M.A., B.Sc. The University, Glasgow.
1868. *Ransom, Edwin, F.R.G.S. 24 Ashburnham-road, Bedford.
1893. ‡Ransom, W. B., M.D. The Pavement, Nottingham.
1863. ‡RANSOM, WILLIAM HENRY, M.D., F.R.S. The Pavement, Nottingham.
1861. †RANSOME, ARTHUR, M.A., M.D., F.R.S. (Local Sec. 1861). Sunnyhurst, Deane Park, Bournemouth.
Ransome, Thomas. Hest Bank, near Lancaster.
1889. §Rapkin, J. B. Sidcup, Kent.
Rashleigh, Jonathan. 3 Cumberland-terrace, Regent's Park, N.W.
1864. ‡Rate, Rev. John, M.A. Fairfield, East Twickenham.
1892. *Rathbone, Miss May. Backwood, Neston, Cheshire.
1895. ‡RATHBONE, W., LL.D. Green Bank, Liverpool.
1874. ‡RAVENSTEIN, E. G., F.R.G.S., F.S.S. (Pres. E, 1891). 2 York-mansions, Battersea Park, S.W.
1889. ‡Rawlings, Edward. Richmond House, Wimbledon Common, Surrey.
1870. ‡Rawlins, G. W. The Hollies, Rainhill, Liverpool.
1866. *RAWLINSON, Rev. Canon GEORGE, M.A. The Oaks, Precincts, Canterbury.
1887. ‡Rawson, Harry. Earlswood, Ellesmere Park, Eccles, Manchester.
1886. ‡Rawson, W. Stepney, M.A. 68 Cornwall-gardens, Queen's-gate, S.W.
1868. *RAYLEIGH, The Right Hon. Lord, M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S. (PRESIDENT, 1884; TRUSTEE, 1883– ; Pres. A, 1882; Council, 1878–83), Professor of Natural Philosophy in the Royal Institution. Terling Place, Witham, Essex.
1895. ‡Raynbird, Hugh, jun. Garrison Gateway Cottage, Old Basing, Basingstoke.
1883. *Rayne, Charles A., M.D., M.R.C.S. St. Mary's Gate, Lancaster.
1897. *Rayner, Edwin Hartree. Teviot Dale, Stockport.
1896. *READ, CHARLES H., F.S.A. (Pres. H, 1899). British Museum, W.C.
1870. ‡READE, THOMAS MELLARD, F.G.S. Blundellsands, Liverpool.
1884. §Readman, J. B., D.Sc., F.R.S.E. 4 Lindsay-place, Edinburgh.
1899. †Reaster, James William. 68 Linden-grove, Nunhead, S.E.
1852. *REDFERN, Professor PETER, M.D. (Pres. D, 1874; VICE-PRESIDENT, 1902). 4 Lower-crescent, Belfast.
1892. ‡Redgrave, Gilbert R., Assoc.Inst.C.E. The Elms, Westgate-road, Beckenham, Kent.
1889. ‡Redmayne, J. M. Harewood, Gateshead.
1889. ‡Redmayne, Norman. 26 Grey-street, Newcastle-upon-Tyne.

Year of Election.

1890\. *Redwood, Boverton, F.R.S.E., F.C.S. Glen Wathen, Church End, Finchley, N.
1861\. ‡Reed, Sir Edward James, K.C.B., F.R.S. Broadway-chambers, Westminster, S.W.
1889\. ‡Reed, Rev. George. Bellingham Vicarage, Bardon Mill, Carlisle.
1891\. *Reed, Thomas A. Bute Docks, Cardiff.
1894\. *Rees, Edmund S. G. Dunscar, Oaken, near Wolverhampton.
1891\. *Rees, I. Treharne, M.Inst.C.E. Highfield, Penarth.
1888\. ‡Rees, W. L. 11 North-crescent, Bedford-square, W.C.
1875\. ‡Rees-Mogg, W. Wooldridge. Cholwell House, near Bristol.
1897\. ‡Reeve, Richard A. 22 Shuter-street, Toronto, Canada.
1901\. *Reid, Andrew T. 10 Woodside Terrace, Glasgow.
1881\. §Reid, Arthur S., M.A., F.G.S. Trinity College, Glenalmond, N.B.
1883\. *Reid, Clement, F.R.S., F.L.S., F.G.S. 28 Jermyn-street, S.W.
1892\. ‡Reid, E. Waymouth, B.A., F.R.S., Professor of Physiology in University College, Dundee.
1889\. ‡Reid, G., Belgian Consul. Leazes House, Newcastle-upon-Tyne.
1901\. *Reid, Hugh. Belmont, Springburn, Glasgow.
1876\. ‡Reid, James. 10 Woodside-terrace, Glasgow.
1901\. §Reid, John. 7 Park Terrace, Glasgow.
1897\. §Reid, T. Whitehead, M.D. St. George's House, Canterbury.
1892\. ‡Reid, Thomas. University College, Dundee.
1887\. *Reid, Walter Francis. Fieldside, Addlestone, Surrey.
1893\. †Reinach, Baron Albert von. Frankfort s. M., Prussia.
1875\. §Reinold, A. W., M.A., F.R.S. (Council 1890–95), Professor of Physics in the Royal Naval College, Greenwich, S.E.
1863\. ‡Renals, E. 'Nottingham Express' Office, Nottingham.
1894\. ‡Rendall, Rev. G. H., M.A. Charterhouse, Godalming.
1891\. *Rendell, Rev. James Robson, B.A. Whinside, Whalley-road, Accrington.
1885\. ‡Rennett, Dr. 12 Golden-square, Aberdeen.
1889\. *Rennie, George B. 20 Lowndes-street, S.W.
1867\. ‡Renny, W. W. 8 Douglas-terrace, Broughty Ferry, Dundee.
1883\. *Reynolds, A. H. Bank House, 135 Lord-street, Southport.
1871\. ‡Reynolds, James Emerson, M.D., D.Sc., F.R.S., Pres.C.S., M.R.I.A. (Pres. B, 1893; Council 1893–99), Professor of Chemistry in the University of Dublin. The Laboratory, Trinity College, Dublin.
1900\. *Reynolds, Miss K. M. 4 Colinette Road, Putney, S.W.
1870\. *Reynolds, Osborne, M.A., LL.D., F.R.S., M.Inst.C.E. (Pres. G, 1887), Professor of Engineering in the Owens College, Manchester. 19 Lady Barn-road, Fallowfield, Manchester.
1896\. ‡Reynolds, Richard S. 73 Smithdown-lane, Liverpool.
1896\. §Rhodes, Albert. Fieldhurst, Liversidge, Yorkshire.
1877\. *Rhodes, John. 360 Blackburn-road, Accrington, Lancashire.
1888\. ‡*Rhodes, John George. Warwick House, 46 St. George's-road, S.W.*
1890\. ‡Rhodes, J. M., M.D. Ivy Lodge, Didsbury.
1884\. ‡Rhodes, Lieut.-Colonel William. Quebec, Canada.
1899\. *Rhys, Professor John, M.A. (Pres. H, 1900). Jesus College, Oxford.
1877\. *Riccardi, Dr. Paul, Secretary of the Society of Naturalists. Riva Muro, 14, Modena, Italy.
1891\. ‡Richards, D. 1 St. Andrew's-crescent, Cardiff.
1891\. ‡Richards, H. M. 1 St. Andrew's-crescent, Cardiff.
1889\. ‡Richards, Professor T. W., Ph.D. Cambridge, Massachusetts, U.S.A.
1888\. *Richardson, Arthur, M.D.
1869\. *Richardson, Charles. 6 The Avenue, Bedford Park, Chiswick.

Year of Election.

1882. ‡Richardson, Rev. George, M.A. Walcote, Winchester.
1884. *Richardson, George Straker. Isthmian Club, Piccadilly, W.
1889. ‡Richardson, Hugh, M.A. Bootham School, York.
1884. *Richardson, J. Clarke. Derwen Fawr, Swansea.
1896. *Richardson, Nelson Moore, B.A., F.E.S. Montevideo, Chickerell, near Weymouth.
1901. *Richardson, Owen Willan. Victoria Crescent, Dewsbury.
1870. ‡Richardson, Ralph, F.R.S.E. 10 Magdala-place, Edinburgh.
1889. ‡Richardson, Thomas, J.P. 7 Windsor-terrace, Newcastle-upon-Tyne.
1876. §Richardson, William Haden. City Glass Works, Glasgow.
1891. ‡Riches, Carlton H. 21 Dumfries-place, Cardiff.
1891. §Riches, T. Harry. 8 Park-grove, Cardiff.
1886. §Richmond, Robert. Heathwood, Leighton Buzzard.
1868. ‡RICKETTS, CHARLES, M.D., F.G.S. 19 Hamilton-square, Birkenhead.
*RIDDELL, Major-General CHARLES J. BUCHANAN, C.B., R.A., F.R.S. Oaklands, Chudleigh, Devon.
1883. *RIDEAL, SAMUEL, D.Sc., F.C.S. 28 Victoria-street, S.W.
1894. §RIDLEY, E. P. (Local Sec. 1895). Burwood, Westerfield Road, Ipswich.
1861. ‡Ridley, John. 19 Belsize-park, Hampstead, N.W.
1884. ‡Ridout, Thomas. Ottawa, Canada.
1881. *Rigg, Arthur. 15 Westbourne Park Villas, W.
1883. *RIGG, EDWARD, M.A. Royal Mint, E.
1892. ‡Rintoul, D., M.A. Clifton College, Bristol.
1873. ‡Ripley, Sir Edward, Bart. Acacia, Apperley, near Leeds.
*RIPON, The Most Hon. the Marquess of, K.G., G.C.S.I., C.I.E., D.C.L., F.R.S., F.L.S., F.R.G.S. 9 Chelsea Embankment, S.W.
1892. ‡Ritchie, R. Peel, M.D., F.R.S.E. 1 Melville-crescent, Edinburgh.
1867. ‡*Ritchie, William. Emslea, Dundee.*
1889. ‡Ritson, U. A. 1 Jesmond-gardens, Newcastle-upon-Tyne.
1900. §Rixon, F. W., B.Sc. 79 Green Lane, Heywood, Lancashire.
1898. §Robb, Alfred A. Lisnabreeny House, Belfast.
1869. *ROBBINS, JOHN, F.C.S. 57 Warrington-crescent, Maida Vale, London, W.
1887. *Roberts, Evan. 30 St. George's-square, Regent's Park, N.W.
1859. ‡Roberts, George Christopher. Hull.
1870. *ROBERTS, ISAAC, D.Sc., F.R.S., F.R.A.S., F.G.S. Starfield, Crowborough, Sussex.
1894. *Roberts, Miss Janora. 14 Alexandra Road, Southport.
1881. ‡Roberts, R. D., M.A., D.Sc., F.G.S. 4 Regent Street, Cambridge.
1879. ‡Roberts, Samuel. The Towers, Sheffield.
1879. ‡Roberts, Samuel, jun. The Towers, Sheffield.
1896. §Roberts, Thomas J. 33 Serpentine-road, Egremont, Cheshire.
1868. *ROBERTS-AUSTEN, Sir W. CHANDLER, K.C.B., D.C.L., F.R.S., V.P.C.S., Chemist to the Royal Mint, and Professor of Metallurgy in the Royal College of Science, London (GENERAL SECRETARY, 1897– ; Pres. B, 1891 ; Council 1886–93). Royal Mint, E.
1883. ‡Robertson, Alexander. Montreal, Canada.
1884. ‡Robertson, E. Stanley, M.A. 43 Waterloo-road, Dublin.
1883. ‡Robertson, George H. Plas Newydd, Llangollen.
1883. ‡Robertson, Mrs. George H. Plas Newydd, Llangollen.
1897. §ROBERTSON, Sir GEORGE S., K.C.S.I. (Pres. E, 1900). 1 Pump Court, Temple, E.C.
1897. §Robertson, Professor J. W. Department of Agriculture, Ottawa, Canada.
1901. *Robertson, Robert, B.Sc., M.Inst.C.E. 154 West George Street, Glasgow.

Year of Election.

1892. †Robertson, W. W. 3 Parliament-square, Edinburgh.
1886. *Robinson, C. R. 27 Elvetham-road, Birmingham.
1898. §Robinson, Charles E., M.Inst.C.E. Selborne, Ashburton, South Devon.
1861. ‡Robinson, Enoch. Dukinfield, Ashton-under-Lyne.
1887. ‡Robinson, Haynes. St. Giles's Plain, Norwich.
1887. §Robinson, Henry, M.Inst.C.E. 13 Victoria-street, S.W.
1901. §Robinson, John, M.Inst.C.E. 8 Vicarage-terrace, Kendal.
1863. ‡Robinson, J. H. 6 Montallo-terrace, Barnard Castle.
1878. ‡Robinson, John L. 198 Great Brunswick-street, Dublin.
1895. *Robinson, Joseph Johnson. 8 Trafalgar-road, Birkdale, Southport.
1876. ‡Robinson, M. E. 6 Park-circus, Glasgow.
1899. *Robinson, Mark, M.Inst.C.E. Overslade, Bilton, near Rugby.
1887. ‡Robinson, Richard. Bellfield Mill, Rochdale.
1881. †Robinson, Richard Atkinson. 195 Brompton-road, S.W.
1875. *Robinson, Robert, M.Inst.C.E. Beechwood, Darlington.
1884. ‡Robinson, Stillman. Columbus, Ohio, U.S.A.
1901. §Robinson, T. Eaton. 33 Cecil Street West, Glasgow.
1863. ‡Robinson, T. W. U. Houghton-le-Spring, Durham.
1891. ‡Robinson, William, Assoc.M.Inst.C.E., Professor of Engineering in University College, Nottingham.
1888. ‡Robottom, Arthur. 3 St. Alban's-villas, Highgate-road, N.W.
1870. *Robson, E. R. Palace Chambers, 9 Bridge-street, Westminster, S.W.
1872. *Robson, William. 5 Gillsland-road, Merchiston, Edinburgh.
1890. ‡Rochester, The Right Rev. E. S. Talbot, D.D., Lord Bishop of. Kennington Park, S.E.
1896. ‡Rock, W. H. 73 Park-road East, Birkenhead.
1896. ‡Rodger, Alexander M. The Museum, Tay Street, Perth.
1885. *Rodger, Edward. 1 Clairmont-gardens, Glasgow.
1885. *Rodriguez, Epifanio. New Adelphi Chambers, 6 Robert Street, Adelphi, W.C.
1866. ‡Roe, Sir Thomas. Grove-villas, Litchurch.
1898. ‡ROGERS, BERTRAM, M.D. (Local Sec. 1898.) 11 York-place, Clifton, Bristol.
1867. ‡Rogers, James S. Rosemill, by Dundee.
1890. *Rogers, L. J., M.A., Professor of Mathematics in Yorkshire College, Leeds. 13 Beech Grove-terrace, Leeds.
1883. ‡Rogers, Major R. Alma House, Cheltenham.
1882. §Rogers, Rev. Canon Saltren, M.A. Tresleigh, St. Austell, Cornwall.
1884. *Rogers, Walter. Hill House, St. Leonards.
1889. †Rogerson, John. Croxdale Hall, Durham.
1897. ‡Rogerson, John. Barrie, Ontario, Canada.
1876. ‡ROLLIT, Sir A. K., M.P., B.A., LL.D., D.C.L., F.R.A.S., Hon. Fellow K.C.L. Thwaite House, Cottingham, East Yorkshire.
1891. ‡Rönnfeldt, W. 43 Park-place, Cardiff.
1894. *Rooper, T. Godolphin. 12 Cumberland-place, Southampton.
1881. *Roper, W. O. Bank-buildings, Lancaster.
1855. *ROSCOE, Sir HENRY ENFIELD, B.A., Ph.D., LL.D., D.C.L., F.R.S. (PRESIDENT, 1887; Pres. B, 1870, 1884; Council 1874–81; Local Sec. 1861). 10 Bramham-gardens, S.W.
1883. *Rose, J. Holland, M.A. 11 Endlesham-road, Balham, S.W.
1894. *ROSE, T. K., D.Sc. 9 Royal Mint, E.
1900. §Rosenhain, Walter, B.A. 185 Monument Road, Edgbaston, Birmingham.
1885. ‡Ross, Alexander. Riverfield, Inverness.

Year of Election.

1887. ‡Ross, Edward. Marple, Cheshire.
1901. §Ross, Major RONALD, F.R.S. 36 Bentley Road, Liverpool.
1859. *Ross, Rev. James Coulman. Wadworth Hall, Doncaster.
1869. *ROSSE, The Right Hon. the Earl of, K.P., B.A., D.C.L., LL.D., F.R.S., F.R.A.S., M.R.I.A. (VICE-PRESIDENT, 1902). Birr Castle, Parsonstown, Ireland.
1891. *Roth, H. Ling. 32 Prescot-street, Halifax, Yorkshire.
1893. ‡Rothera, G. B. Sherwood Rise, Nottingham.
1865. *Rothera, George Bell. Hazlewood, Forest Grove, Nottingham.
1901. *Rottenburg, Paul, LL.D. Care of Leister, Bock & Co., Glasgow.
1899. *Round, J. C., M.R.C.S. 19 Crescent-road, Sydenham Hill, S.E.
1884. *Rouse, M. L. Hollybank, Hayne Road, Beckenham.
1901. §Rouse, W. H. D. Cambridge.
1861. ‡ROUTH, EDWARD J., M.A., D.Sc., F.R.S., F.R.A.S., F.G.S. St. Peter's College, Cambridge.
1883. ‡Rowan, Frederick John. 134 St. Vincent-street, Glasgow.
1865. ‡*Rowe, Rev. John. 13 Hampton Road, Forest Gate, Essex.*
1877. ‡ROWE, J. BROOKING, F.L.S., F.S.A. 16 Lockyer-street, Plymouth.
1890. ‡Rowley, Walter, F.S.A. Alderhill, Meanwood, Leeds.
1881. *ROWNTREE, JOHN S. Mount Villas, York.
1881. *Rowntree, Joseph. 38 St. Mary's, York.
1876. ‡Roxburgh, John. 7 Royal Bank-terrace, Glasgow.
1885. ‡Roy, John. 33 Belvidere-street, Aberdeen.
1899. ‡Rubie, G. S. Belgrave House, Folkestone-road, Dover.
1875. *RÜCKER, A. W., M.A., D.Sc., Sec.R.S., Principal of the University of London (PRESIDENT, 1901; TRUSTEE, 1898– ; TREASURER, 1891–98; Pres. A, 1894; Council 1888–91). 19 Gledhow-gardens, South Kensington, S.W.
1892. §Rücker, Mrs. Levetleigh, Dane-road, St. Leonards-on-Sea.
1869. §RUDLER, F. W., F.G.S. The Museum, Jermyn-street, S.W.
1901. *Rudorf, L. C. G. 26 Weston Park, Crouch End, N.
1882. ‡Rumball, Thomas, M.Inst.C.E. 1 Victoria Villas, Brondesbury, N.W.
1896. *Rundell, T. W., F.R.Met.Soc. 25 Castle-street, Liverpool.
1887. ‡Ruscoe, John. Ferndale, Gee Cross, near Manchester.
1889. ‡Russell, The Right Hon. Earl. Amberley Cottage, Maidenhead.
1875. *Russell, The Hon. F. A. R. Dunrozel, Haslemere.
1884. ‡Russell, George. 13 Church-road, Upper Norwood, S.E.
Russell, John. 39 Mountjoy-square, Dublin.
1890. ‡Russell, Sir J. A., LL.D. Woodville, Canaan-lane, Edinburgh.
1883. *Russell, J. W. 16 Bardwell-road, Oxford.
1852. *Russell, Norman Scott. Arts Club, Hanover-square, W.
1876. ‡Russell, Robert, F.G.S. 1 Sea View, St. Bees, Carnforth.
1886. ‡Russell, Thomas H. 3 Newhall-street, Birmingham.
1852. *RUSSELL, WILLIAM J., Ph.D., F.R.S., V.P.C.S. (Pres. B, 1873; Council 1873–80). 34 Upper Hamilton-terrace, St. John's Wood, N.W.
1886. ‡Rust, Arthur. Eversleigh, Leicester.
1897. ‡Rutherford, A. Toronto, Canada.
1891. ‡Rutherford, George. Dulwich House, Pencisely-road, Cardiff.
1887. ‡Rutherford, William. 7 Vine-grove, Chapman-street, Hulme, Manchester.
1889. ‡Ryder, W. J. H. 52 Jesmond-road, Newcastle-upon-Tyne.
1897. ‡Ryerson, G. S., M.D. Toronto, Canada.
1898. §Ryland, C. J. Southerndon House, Clifton, Bristol.
1865. ‡Ryland, Thomas. The Redlands, Erdington, Birmingham.

Year of Election.

1883. ‡Sadler, Robert. 7 Lulworth-road, Birkdale, Southport.
1871. ‡Sadler, Samuel Champernowne. 186 Aldersgate-street, E.C.
1886. ‡*St. Clair, George, F.G.S. 225 Castle Road, Cardiff.*
1893. ‡SALISBURY, The Most Hon. the Marquis of, K.G., D.C.L., F.R.S. (PRESIDENT, 1894). 20 Arlington-street, S.W.
1881. ‡Salkeld, William. 4 Paradise-terrace, Darlington.
1857. ‡SALMON, Rev. GEORGE, D.D., D.C.L., LL.D., F.R.S. (Pres. A, 1878). Provost of Trinity College, Dublin.
1873. *Salomons, Sir David, Bart., F.G.S. Broomhill, Tunbridge Wells.
1887. ‡Samson, C. L. Carmona, Kersal, Manchester.
1861. *Samson, Henry. 6 St. Peter's-square, Manchester.
1894. ‡SAMUELSON, The Right Hon. Sir BERNHARD, Bart., F.R.S., M.Inst.C.E. 56 Prince's-gate, S.W.
1878. ‡Sanders, Alfred, F.L.S. 2 Clarence-place, Gravesend, Kent.
1883. ‡Sanderson, Deputy Surgeon-General Alfred. East India United Service Club, St. James's-square, S.W.
1893. ‡Sanderson, F. W., M.A. The School, Oundle.
1872. §SANDERSON, Sir J. S. BURDON, Bart., M.D., D.Sc., LL.D., D.C.L., F.R.S., F.R.S.E. (PRESIDENT, 1893; Pres. D, 1889; Council 1877-84), Regius Professor of Medicine in the University of Oxford. 64 Banbury-road, Oxford.
1883. ‡Sanderson, Lady Burdon. 64 Banbury-road, Oxford.
Sandes, Thomas, A.B. Sallow Glin, Tarbert, Co. Kerry.
1896. §Saner, John Arthur, Assoc.M.Inst.C.E. Highfield, Northwich.
1896. ‡Saner, Mrs. Highfield, Northwich.
1892. §Sang, William D. Tylehurst, Kirkcaldy, Fife.
1886. §Sankey, Percy E. 44 Russell Square, W.C.
1896. *Sargant, Miss Ethel. Quarry Hill, Reigate.
1896. ‡Sargant, W. L. Quarry Hill, Reigate.
1901. §Sarruf, N. Y. 'Al Mokattam,' Cairo.
1886. ‡Sanborn, John Wentworth. Albion, New York, U.S.A.
1886. ‡Saundby, Robert, M.D. 83A Edmund Street, Birmingham.
1900. *Saunder, S. A. Fir Holt, Crowthorne, Berks.
1868. ‡Saunders, A., M.Inst.C.E. King's Lynn.
1886. ‡Saunders, C. T. Temple-row, Birmingham.
1881. ‡SAUNDERS, HOWARD, F.L.S., F.Z.S. 7 Radnor-place, W.
1883. ‡Saunders, Rev. J. C. Cambridge.
1846. ‡SAUNDERS, TRELAWNEY W., F.R.G.S. 3 Elmfield on the Knowles, Newton Abbot, Devon.
1884. ‡SAUNDERS, Dr. WILLIAM. Experimental Farm, Ottawa, Canada.
1891. ‡Saunders, W. H. R. Llanishen, Cardiff.
1884. ‡Saunderson, C. E. 26 St. Famille-street, Montreal, Canada.
1887. ‡Savage, Rev. Canon E. B., M.A., F.S.A. St. Thomas' Vicarage, Douglas, Isle of Man.
1871. ‡Savage, W. D. Ellerslie House, Brighton.
1883. ‡Savage, W. W. 109 St. James's-street, Brighton.
1883. ‡Savery, G. M., M.A. The College, Harrogate.
1901. §Sawers, W. D. 1 Athole Gardens Place, Glasgow.
1887. §SAYCE, Rev. A. H., M.A., D.D. (Pres. H, 1887), Professor of Assyriology in the University of Oxford. Queen's College, Oxford.
1884. ‡Sayre, Robert H. Bethlehem, Pennsylvania, U.S.A.
1883. *Scarborough, George. Whinney Field, Halifax, Yorkshire.
1884. ‡Scarth, William Bain. Winnipeg, Manitoba, Canada.
1879. *SCHÄFER, E. A., LL.D., F.R.S., M.R.C.S. (GEN. SEC. 1895-1900; Pres. I, 1894; Council 1887-93), Professor of Physiology in the University of Edinburgh.

Year of Election.

1888. *SCHARFF, ROBERT F., Ph.D., B.Sc., Keeper of the Natural History Department, Museum of Science and Art, Dublin.
1880. *Schemmann, Louis Carl. Hamburg. (Care of Messrs. Allen Everitt & Sons, Birmingham.)
1892. †Schloss, David F. 1 Knaresborough-place, S.W.
1842. Schofield, Joseph. Stubley Hall, Littleborough, Lancashire.
1887. ‡Schofield, T. Thornfield, Talbot-road, Old Trafford, Manchester.
1883. ‡Schofield, William. Alma-road, Birkdale, Southport.
1885. §Scholes, L. 14 Abington Road, Brooklands, Cheshire.
SCHUNCK, EDWARD, Ph.D., F.R.S., F.C.S. (Pres. B, 1887). Oaklands, Kersal Moor, Manchester.
1873. *SCHUSTER, ARTHUR, Ph.D., F.R.S., F.R.A.S. (Pres. A, 1892; Council 1887–93), Professor of Physics in the Owens College. Kent House, Victoria-park, Manchester.
1847. *SCLATER, PHILIP LUTLEY, M.A., Ph.D., F.R.S., F.L.S., F.G.S., F.R.G.S., Sec.Z.S. (GENERAL SECRETARY 1876–81; Pres. D, 1875; Council 1864–67, 1872–75). 3 Hanover-square, W.
1883. *SCLATER, W. LUTLEY, M.A., F.Z.S. South African Museum, Cape Town.
1867. ‡SCOTT, ALEXANDER. Clydesdale Bank, Dundee.
1881. *SCOTT, ALEXANDER, M.A., D.Sc., F.R.S., Sec.C.S. Royal Institution, Albemarle-street, W.
1878. *Scott, Arthur William, M.A., Professor of Mathematics and Natural Science in St. David's College, Lampeter.
1881. ‡Scott, Miss Charlotte Angas, D.Sc. Bryn Mawr College, Pennsylvania, U.S.A.
1889. *SCOTT, D. H., M.A., Ph.D., F.R.S., F.L.S. (GENERAL SECRETARY, 1900– ; Pres. K, 1896). The Old Palace, Richmond, Surrey.
1885. ‡Scott, George Jamieson. Bayview House, Aberdeen.
1897. ‡Scott, James. 173 Jameson-avenue, Toronto, Canada.
1857. *SCOTT, ROBERT H., M.A., D.Sc., F.R.S., F.R.Met.S. 6 Elm Park-gardens, S.W.
1884. *Scott, Sydney C. 28 The Avenue, Gipsy Hill, S.E.
1895. §Scott-Elliot, Professor G. F., M.A., B.Sc., F.L.S. Ainslea, Scotstounhill, Glasgow.
1881. *Scrivener, A. P. Haglis House, Wendover.
1883. ‡Scrivener, Mrs. Haglis House, Wendover.
1895. §Scull, Miss E. M. L. The Pines, 10 Langland-gardens, Hampstead, N.W.
1890. §Searle, G. F. C., M.A. 20 Trumpington Street, Cambridge.
1859. ‡Seaton, John Love. The Park, Hull.
1880. †SEDGWICK, ADAM, M.A., F.R.S. (Pres. D, 1899). Trinity College, and 4 Cranmer Road, Cambridge.
1861. *SEELEY, HARRY GOVIER, F.R.S., F.L.S., F.G.S., F.R.G.S., F.Z.S., Professor of Geology in King's College, London. 25 Palace Gardens-terrace, Kensington, W.
1891. ‡Selby, Arthur L., M.A., Assistant Professor of Physics in University College, Cardiff.
1893. ‡SELBY-BIGGE, L. A., M.A. Charity Commission, Whitehall, S.W.
1855. ‡Seligman, H. L. 27 St. Vincent-place, Glasgow.
1879. ‡Selim, Adolphus. 21 Mincing-lane, E.C.
1897. ‡Selous, F. C., F.R.G.S. Alpine Lodge, Worplesden, Surrey.
1884. ‡SELWYN, A. R. C., C.M.G., F.R.S., F.G.S. Ottawa, Canada.
1885. ‡Semple, Dr. A. United Service Club, Edinburgh.
1888. *SENIER, ALFRED, M.D., Ph.D., F.C.S., Professor of Chemistry in Queen's College, Galway.

Year of
Election.
1888. *Sennett, Alfred R., A.M.Inst.C.E. 304 King's Road, Chelsea, S.W.
1901. §Service, Robert. Janefield Park, Maxwelltown, Dumfries.
1870. *Sephton, Rev. J. 90 Huskisson-street, Liverpool.
1892. ‡Seton, Miss Jane. 37 Candlemaker-row, Edinburgh.
1895. *Seton-Karr, H. W. 31 Lingfield Road, Wimbledon, Surrey.
1892. §SEWARD, A. C., M.A., F.R.S., F.G.S. (Council 1901–). Westfield, Huntingdon-road, Cambridge.
1891. ‡Seward, Edwin. 55 Newport-road, Cardiff.
1868. ‡Sewell, Philip E. Catton, Norwich.
1899. §Seymour, Henry, J. 16 Wellington-road, Dublin.
1891. ‡Shackell, E. W. 191 Newport-road, Cardiff.
1888. ‡Shackles, Charles F. Hornsea, near Hull.
1883. ‡Shadwell, John Lancelot. 30 St. Charles-square, Ladbroke Grove-road, W.
1902. §§SHAFTESBURY, The Earl of (VICE-PRESIDENT, 1902). Salisbury.
1871. *Shand, James. Parkholme, Elm Park-gardens, S.W.
1867. ‡Shanks, James. Dens Iron Works, Arbroath, N.B.
1881. ‡Shann, George, M.D. Petergate, York.
1878. ‡SHARP, DAVID, M.A., M.B., F.R.S., F.L.S. Museum of Zoology, Cambridge.
1896. ‡Sharp, Mrs. E. 65 Sankey-street, Warrington.
Sharp, Rev. John, B.A. Horbury, Wakefield.
1886. ‡Sharp, T. B. French Walls, Birmingham.
1883. ‡Sharples, Charles H. 7 Fishergate, Preston.
1870. ‡Shaw, Duncan. Cordova, Spain.
1896. ‡Shaw, Frank. Ellerslie, Aigburth-drive, Liverpool.
1865. ‡Shaw, George. Cannon-street, Birmingham.
1870. ‡Shaw, John. 21 St. James's-road, Liverpool.
1891. ‡Shaw, Joseph. 1 Temple-gardens, E.C.
1889. *Shaw, Mrs. M. S., B.Sc. Sydenham Damard Rectory, Tavistock.
1883. *SHAW, W. N., M.A., F.R.S. (Council 1895-1900). Meteorological Office, Victoria-street, S.W.
1883. ‡Shaw, Mrs. W. N. 10 Moreton Gardens, South Kensington, S.W.
1891. ‡Sheen, Dr. Alfred. 23 Newport-road, Cardiff.
1878. ‡Shelford, William, M.Inst.C.E. 35A Great George-street, S.W.
1865. ‡Shenstone, Frederick S. Sutton Hall, Barcombe, Lewes.
1881. ‡SHENSTONE, W. A., F.R.S. Clifton College, Bristol.
1885. ‡Shepherd, Rev. Alexander. Ecclesmechen, Uphall, Edinburgh.
1890. ‡Shepherd, J. Care of J. Redmayne, Esq., Grove House, Headingley, Leeds.
1883. ‡Shepherd, James. Birkdale, Southport.
1900. §Sheppard, Thomas, F.G.S. 432 Holderness Road, Hull.
1883. ‡Sherlock, David. Rahan Lodge, Tullamore, Dublin.
1883. ‡Sherlock, Mrs. David. Rahan Lodge, Tullamore, Dublin.
1883. ‡Sherlock, Rev. Edgar. Bentham Rectory, *viâ* Lancaster.
1896. §SHERRINGTON, C. S., M.D., F.R.S., Professor of Physiology in University College, Liverpool. 16 Grove-park, Liverpool.
1888. *Shickle, Rev. C. W., M.A. 5 Cavendish Crescent, Bath.
1886. ‡Shield, Arthur H. 35A Great George-street, S.W.
1892. ‡Shields, John, D.Sc., Ph.D. Dolphingston, Tranent, Scotland.
1901. §Shields, Thomas, M.A., B.Sc. Englefield Green, Surrey.
1883. *Shillitoe, Buxton, F.R.C.S. 2 Frederick-place, Old Jewry, E.C.
1867. ‡Shinn, William C. 39 Varden's-road, Clapham Junction, S.W.
1887. *SHIPLEY, ARTHUR E., M.A. Christ's College, Cambridge.
1889. ‡Shipley, J. A. D. Saltwell Park, Gateshead.
1885. ‡Shirras, G. F. 16 Carden-place, Aberdeen.

Year of Election.

1883. †Shone, Isaac. Pentrefelin House, Wrexham.
1870. *SHOOLBRED, J. N., M.Inst.C.E. 47 Victoria-street, S.W.
1888. †Shoppee, C. H. 22 John-street, Bedford-row, W.C.
1897. †SHORE, Dr. LEWIS E. St. John's College, Cambridge.
1875. †SHORE, THOMAS W., F.G.S. 105 Ritherdon-road, Upper Tooting, S.W.
1882. †SHORE, T. W., M.D., B.Sc., Lecturer on Comparative Anatomy at St. Bartholomew's Hospital. Heathfield, Alleyn Park, Dulwich, S.E.
1901. §Short, Peter M., B.Sc. 19 Manchester Road, Southport.
1897. †Shortt, Professor Adam, M.A. Queen's University, Kingston, Ontario, Canada.
1889. †Sibley, Walter K., B.A., M.B. 8 Duke Street-mansions, Grosvenor-square, W.
1883. †Sibly, Miss Martha Agnes. Flook House, Taunton.
1883. *Sidebotham, Edward John. Erlesdene, Bowdon, Cheshire.
1883. *Sidebotham, James Nasmyth. Parkfield, Altrincham, Cheshire.
1877. *Sidebotham, Joseph Watson. Merlewood, Bowdon, Cheshire.
Sidney, M. J. F. Cowpen, Newcastle-upon-Tyne.
1873. *SIEMENS, ALEXANDER, M.Inst.C.E. 7 Airlie-gardens, Campden Hill, W.
1878. †SIGERSON, Professor GEORGE, M.D., M.R.I.A. 3 Clare Sreet, Dublin.
1859. †Sim, John. Hardgate, Aberdeen.
1871. †Sime, James. Craigmount House, Grange, Edinburgh.
1898. †Simmons, Henry. Kingsland House, Whiteladies-road, Clifton, Bristol.
1862. †Simms, James. 138 Fleet-street, E.C.
1874. †Simms, William. Upper Queen-street, Belfast.
1876. †Simon, Frederick. 24 Sutherland-gardens, W.
1847. †SIMON, Sir JOHN, K.C.B., M.D., D.C.L., F.R.S. (Council 1870-72). 40 Kensington-square, W.
1901. §Simpson, Rev. A., B.Sc., F.G.S. 28 Myrtle Park, Crosshill, Glasgow.
1871. *SIMPSON, ALEXANDER R., M.D., Professor of Midwifery in the University of Edinburgh. 52 Queen-street, Edinburgh.
1883. †Simpson, Byron R. 7 York-road, Birkdale, Southport.
1887. †Simpson, F. Estacion Central, Buenos Ayres.
1859. †Simpson, John. Maykirk, Kincardineshire.
1863. †Simpson, J. B., F.G.S. Hedgefield House, Blaydon-on-Tyne.
1901. §Simpson, J. Y., D.Sc., F.R.S.E. 52 Queen Street, Edinburgh.
1857. †SIMPSON, MAXWELL, M.D., LL.D., F.R.S., F.C.S. (Pres. B, 1878). 7 Darnley Road, Holland Park Avenue, W.
1894. §Simpson, Thomas, F.R.G.S. Fennymere, Castle Bar, Ealing, W.
1883. †Simpson, Walter M. 7 York-road, Birkdale, Southport.
1896. *Simpson, W., F.G.S. The Gables, Halifax.
1887. †Sinclair, Dr. 268 Oxford-street, Manchester.
1901. §Sinclair, Alexander. Ajmere Lodge, Langside, Glasgow.
1874. †SINCLAIR, Right Hon. THOMAS (Local Sec. 1874; VICE PRESIDENT, 1902). Dunedin, Belfast.
1897. †Sinnott, James. Bank of England-chambers, 12 Broad-street, Bristol.
1864. *Sircar, The Hon. Mahendra Lal, M.D., C.I.E. 51 Sankaritola, Calcutta.
1892. †Sisley, Richard, M.D. 11 York-street, Portman-square, W.
1883. †Skillicorne, W. N. 9 Queen's-parade, Cheltenham.
1885. †Skinner, Provost. Inverurie, N.B.
1898. †Skinner, Sidney. Cromwell House, Trumpington, Cambridgeshire.

Year of Election.

1888. §SKRINE, H. D., J.P., D.L. Claverton Manor, Bath.
1889. §Slater, Matthew B., F.L.S. Malton, Yorkshire.
1884 ‡Slattery, James W. 9 Stephen's-green, Dublin.
1877. ‡Sleeman, Rev. Philip, L.Th., F.R.A.S. 65 Pembroke-road, Clifton, Bristol.
1891. §Slocombe, James. Redland House, Fitzalan, Cardiff.
1884. ‡Slooten, William Venn. Nova Scotia, Canada.
1849. ‡Sloper, George Elgar. Devizes.
1887. §Small, Evan W., M.A., B.Sc., F.G.S. The Mount, Radbourne-street, Derby.
1887. §Small, William. Lincoln-circus, The Park, Nottingham.
1885. ‡Smart, James. Valley Works, Brechin, N.B.
1889. *Smart, William, LL.D. Nunholme, Dowanhill, Glasgow.
1898. ‡Smeeth, W. F., M.A., F.G.S. Mysore, India.
1876. ‡Smellie, Thomas D. 213 St. Vincent-street, Glasgow.
1877. ‡Smelt, Rev. Maurice Allen, M.A., F.R.A.S. Heath Lodge, Cheltenham.
1890. ‡Smethurst, Charles. Palace House, Harpurhey, Manchester.
1876. ‡Smieton, James. Panmure Villa, Broughty Ferry, Dundee.
1867. ‡Smieton, Thomas A. Panmure Villa, Broughty Ferry, Dundee.
1892. ‡*Smith, Adam Gillies, F.R.S.E.* 35 *Drumsheugh-gardens, Edinburgh.*
1892. ‡Smith, Alexander, B.Sc., Ph.D., F.R.S.E. The University, Chicago, Illinois, U.S.A.
1897. ‡Smith, Andrew, Principal of the Veterinary College, Toronto, Canada.
1901. *Smith, Miss Annie Lorraine. 8 Essex Grove, Norwood, S.E.
1874. *Smith, Benjamin Leigh, F.R.G.S. Oxford and Cambridge Club, Pall Mall, S.W.
1887. ‡Smith, Bryce. Rye Bank, Chorlton-cum-Hardy, Manchester.
1873. ‡Smith, C. Sidney College, Cambridge.
1887. *Smith, Charles. 739 Rochdale-road, Manchester.
1889. *Smith, Professor C. Michie, B.Sc., F.R.S.E., F.R.A.S. The Observatory, Madras.
1865. ‡*Smith, David, F.R.A.S.* 40 *Bennett's-hill, Birmingham.*
1886. ‡Smith, Edwin. 33 Wheeley's-road, Edgbaston, Birmingham.
1886. *Smith, Mrs. Emma. Hencotes House, Hexham.
1886. ‡Smith, E. Fisher, J.P. The Priory, Dudley.
1900. §Smith, E. J. Grange House, Westgate Hill, Bradford.
1886. ‡Smith, E. O. Council House, Birmingham.
1892. ‡Smith, E. Wythe. 66 College-street, Chelsea, S.W.
1866. *Smith, F. C. Bank, Nottingham.
1897. ‡Smith, Sir Frank. 54 King-street East, Toronto, Canada.
1901. §Smith, F. B. South Eastern Agricultural College, Wye.
1885. ‡Smith, Rev. G. A., M.A. 22 Sardinia-terrace, Glasgow.
1897. ‡Smith, G. Elliot, M.D. St. John's College, Cambridge.
1860. *Smith, Heywood, M.A., M.D. 18 Harley-street, Cavendish-square, W.
1870. ‡Smith, H. L. Crabwall Hall, Cheshire.
1889. *Smith, H. Llewellyn, B.A., B.Sc., F.S.S. 4 Harcourt-buildings, Inner Temple, E.C.
1888. ‡Smith, H. W. Owens College, Manchester.
1885. ‡Smith, Rev. James, B.D. Manse of Newhills, N.B.
1876. *Smith, J. Guthrie. 5 Kirklee-gardens, Kelvinside, Glasgow.
Smith, John Peter George. Sweyney Cliff, Coalport, Iron Bridge, Shropshire.
1901. §SMITH, J. PARKER, M.P. Jordanhill, Glasgow.
1883. ‡Smith, M. Holroyd. Royal Insurance Buildings, Crossley-street, Halifax.

Year of Election.

1885. ‡SMITH, ROBERT H., Assoc.M.Inst.C.E. 53 Victoria-street, S.W.
1870. ‡Smith, Samuel. Bank of Liverpool, Liverpool.
1873. ‡Smith, Sir Swire. Lowfield, Keighley, Yorkshire.
1867. ‡Smith, Thomas. Dundee.
1867. ‡Smith, Thomas. Poole Park Works, Dundee.
1859. ‡Smith, Thomas James, F.G.S., F.C.S. Hornsea Burton, East Yorkshire.
1894. §Smith, T. Walrond. 14 Calverley-park, Tunbridge Wells.
1884. ‡Smith, Vernon. 127 Metcalfe-street, Ottawa, Canada.
1892. ‡Smith, Walter A. 120 Princes-street, Edinburgh.
1885. *Smith, Watson. University College, Gower-street, W.C.
1896. *Smith, Rev. W. Hodson. Newquay, Cornwall.
1852. ‡Smith, William. Eglinton Engine Works, Glasgow.
1876. ‡Smith, William. 12 Woodside-place, Glasgow.
1883. ‡SMITHELLS, ARTHUR, B.Sc., F.R.S. (Local Sec. 1890). Professor of Chemistry in the Yorkshire College, Leeds.
1883. ‡Smithson, Edward Walter. 13 Lendal, York.
1883. ‡Smithson, Mrs. 13 Lendal, York.
1882. ‡Smithson, T. Spencer. Facit, Rochdale.
1874. ‡Smoothy, Frederick. Bocking, Essex.
1883. ‡Smyth, Rev. Christopher. Firwood, Chalford, Stroud.
1857. *SMYTH, JOHN, M.A., F.C.S., F.R.M.S., M.Inst.C.E.I. Milltown, Banbridge, Ireland.
1888. *SNAPE, H. LLOYD, D.Sc., Ph.D. Balholm, Lathom Road, Southport.
1888. ‡*Snell, Albion T. Brightside, Salusbury Road, Brondesbury, N.W.*
1878. §Snell, H. Saxon. 22 Southampton-buildings, W.C.
1889. ‡Snell, W. H. Lancaster Lodge, Amersham Road, Putney, S.W.
1898. ‡Snook, Miss L. B. V. 13 Clare-road, Cotham, Bristol.
1879. *SOLLAS, W. J., M.A., D.Sc., F.R.S., F.R.S.E., F.G.S. (Pres. C, 1900; Council 1900–), Professor of Geology in the University of Oxford. 169 Woodstock-road, Oxford.
1892. *SOMERVAIL, ALEXANDER. The Museum, Torquay.
1901. §Somerville, Alexander, F.L.S. 4 Bute Mansions, Hillhead, Glasgow.
1900. *SOMERVILLE, W. Board of Agriculture, Whitehall, S.W.
1859. *SORBY, H. CLIFTON, LL.D., F.R.S., F.G.S. (Pres. C, 1880; Council 1879–86; Local Sec. 1879). Broomfield, Sheffield.
1879. *Sorby, Thomas W. Storthfield, Ranmoor, Sheffield.
1901. §Sorley, Robert. The Firs, Partickill, Glasgow.
1888. ‡SORLEY, Professor W. R. The University, Cambridge.
1880. ‡Southall, Alfred. Carrick House, Richmond Hill-road, Birmingham.
1865. *Southall, John Tertius. Parkfields, Ross, Herefordshire.
1887. §Sowerbutts, Eli, F.R.G.S. 16 St. Mary's Parsonage, Manchester.
1883. ‡Spanton, William Dunnett, F.R.C.S. Chatterley House, Hanley, Staffordshire.
1890. ‡Spark, F. R. 29 Hyde-terrace, Leeds.
1893. *Speak, John. Kirton Grange, Kirton, near Boston.
1887. ‡Spencer, F. M. Fernhill, Knutsford.
1884. ‡Spencer, John, M.Inst.M.E. Globe Tube Works, Wednesbury.
1889. *Spencer, John. Newbiggin House, Kenton, Newcastle-upon-Tyne.
1891. *Spencer, Richard Evans. The Old House, Llandaff.
1864. *Spicer, Henry, B.A., F.L.S., F.G.S. 14 Aberdeen Park, Highbury, N.
1894. ‡Spiers, A. H. Newton College, South Devon.
1864. *SPILLER, JOHN, F.C.S. 2 St. Mary's-road, Canonbury, N.
1864. *Spottiswoode, W. Hugh, F.C.S. 107 Sloane-street, S.W.
1854. *SPRAGUE, THOMAS BOND, M.A., LL.D., F.R.S.E. 29 Buckingham-terrace, Edinburgh.

Year of
Election.

1883. ‡Spratling, W. J., B.Sc., F.G.S. Maythorpe, 74 Wickham-road, Brockley, S.E.
1888. ‡Spreat, John Henry. Care of Messrs. Vines & Froom, 75 Aldersgate-street, E.C.
1897. *§Squire, W. Stevens, Ph.D. Clarendon House, 30 St. John's Wood Park, N.W.
1888. *Stacy, J. Sargeant. 143 Lansdown Road, Seven Kings, Essex.
1897. ‡Stafford, Joseph. Morrisburg, Ontario, Canada.
1884. ‡Stancoffe, Frederick. Dorchester-street, Montreal, Canada.
1892. ‡Stanfield, Richard, Assoc.M.Inst.C.E., F.R.S.E., Professor of Engineering in the Heriot Watt College, Edinburgh. 49 Mayfield-road, Edinburgh.
1883. *Stanford, Edward, jun., F.R.G.S. Thornbury, High Street, Bromley, Kent.
1881. *Stanley, William Ford, F.G.S. Cumberlow, South Norwood, S.E.
1883. ‡Stanley, Mrs. Cumberlow, South Norwood, S.E.
1894. *Stansfield, Alfred, D.Sc. Royal College of Science, S.W.
1900. *Stansfield, H., B.Sc. Municipal Technical School, Blackburn.
Stapleton, M. H., M.B., M.R.I.A. 1 Mountjoy-place, Dublin.
1899. ‡Starling, E. H., M.D., F.R.S., Professor of Physiology in University College, London. 8 Park-square West, N.W.
1876. ‡Starling, John Henry, F.C.S. 32 Craven-street, Strand, W.C.
1899. §Statham, William. The Redings, Totteridge, Herts.
1898. ‡Stather, J. W., F.G.S. 16 Louis-street, Hull.
Staveley, T. K. Ripon, Yorkshire.
1894. ‡Stavert, Rev. W. J., M.A. Burnsall Rectory, Skipton-in-Craven, Yorkshire.
1873. *Stead, Charles. Red Barns, Freshfield, Liverpool.
1900. *Stead, J. E. Laboratory and Assay Office, Middlesbrough.
1881. ‡Stead, W. H. Orchard-place, Blackwall, E.
1881. ‡Stead, Mrs. W. H. Orchard-place, Blackwall, E.
1884. ‡Stearns, Sergeant P. U.S. Consul-General, Montreal, Canada.
1892. *Stebbing, Rev. Thomas R. R., M.A., F.R.S. Ephraim Lodge, The Common, Tunbridge Wells.
1896. *Stebbing, W. P. D., F.G.S. 169 Gloucester-terrace, W.
1891. ‡Steeds, A. P. 15 St. Helen's-road, Swansea.
1873. ‡Steinthal, G. A. 15 Hallfield-road, Bradford, Yorkshire.
1884. ‡Stephen, George. 140 Drummond-street, Montreal, Canada.
1884. ‡Stephen, Mrs. George. 140 Drummond-street, Montreal, Canada.
1884. *Stephens, W. Hudson. Low-Ville, Lewis County, New York, U.S.A.
1879. *Stephenson, Sir Henry, J.P. The Glen, Sheffield.
1901. §Steven, William. 420 Sauchiehall Street, Glasgow.
1901. §Steven, Mrs. W. 420 Sauchiehall Street, Glasgow.
1880. *Stevens, J. Edward, LL.B. Le Mayals, Blackpyl, R.S.O.
1900. ‡Stevens, Frederick (Local Sec. 1900). Town Clerk's Office, Bradford.
1892. ‡Stevenson, D. A., B.Sc., F.R.S.E., M.Inst.C.E. 84 George-street, Edinburgh.
1863. *Stevenson, James C. Westoe, South Shields.
1890. *Steward, Rev. Charles J., F.R.M.S. The Cedars, Anglesea-road, Ipswich.
1885. *Stewart, Rev. Alexander, M.D., LL.D. Murtle, Aberdeen.
1864. ‡Stewart, Charles, M.A., F.R.S., F.L.S., Hunterian Professor of Anatomy and Conservator of the Museum, Royal College of Surgeons, Lincoln's Inn Fields, W.C.
1892. ‡Stewart, C. Hunter. 3 Carlton-terrace, Edinburgh.
1885. ‡Stewart, David. Banchory House, Aberdeen.

Year of Election.

1886. *Stewart, Duncan. 14 Windsor-terrace, Kelvinside, Glasgow.
1875. *Stewart, James, B.A., F.R.C.P.Ed. Dunmurry, Sneyd Park, near Clifton, Gloucestershire.
1901. *Stewart, John Joseph, M.A., B.Sc. 53 Cæsar Road, Newport, Mon.
1892. ‡Stewart, Samuel. Knocknairn, Bagston, Greenock.
1901. §Stewart, Thomas. St. George's Chambers, Cape Town.
1901. §Stewart, Walter, M.A., D.Sc. Gartsherrie, Coatbridge.
1901. §Stewart, William. Violet Grove House, St. George's Road, Glasgow.
1867. ‡Stirling, Dr. D. Perth.
1876. ‡STIRLING, WILLIAM, M.D., D.Sc., F.R.S.E., Professor of Physiology in the Owens College, Manchester.
1867. *Stirrup, Mark, F.G.S. Stamford-road, Bowdon, Cheshire.
1901. *Stobo, Thomas. Somerset House, Garelochhead, Scotland.
1865. *Stock, Joseph S. St. Mildred's, Walmer.
1890. ‡Stockdale, R. The Grammar School, Leeds.
1883. *STOCKER, W. N., M.A. Brasenose College, Oxford.
1898. ‡Stoddart, F. Wallis, F.I.C. Grafton Lodge, Sneyd Park, Bristol.
1845. *STOKES, Sir GEORGE GABRIEL, Bart., M.A., D.C.L., LL.D., D.Sc., F.R.S. (PRESIDENT, 1869; Pres. A, 1854, 1862; Council 1852–58, 1864–67), Lucasian Professor of Mathematics in the University of Cambridge. Lensfield Cottage, Cambridge.
1898. *Stokes, Professor George J., M.A. Riversdale, Sunday's Well, Cork.
1887. ‡Stone, E. D., F.C.S. Rose Lea, Alderley Edge, Cheshire.
1893. *Stone, F. J. Radley College, Abingdon.
1888. †STONE, JOHN. 15 Royal-crescent, Bath.
1886. ‡Stone, Sir J. Benjamin, M.P. The Grange, Erdington, Birmingham.
1886. †Stone, J. H. Grosvenor-road, Handsworth, Birmingham.
1874. ‡Stone, J. Harris, M.A., F.L.S., F.C.S. 3 Dr. Johnson's-buildings, Temple, E.C.
1876. ‡Stone, Octavius C., F.R.G.S. Rothbury House, Westcliff-gardens, Bournemouth.
1857. †STONEY, BINDON B., LL.D., F.R.S., M.Inst.C.E., M.R.I.A., Engineer of the Port of Dublin. 14 Elgin-road, Dublin.
1895. *Stoney, Miss Edith A. 30 Ledbury Road, Bayswater. W.
1878. *Stoney, G. Gerald. Oakley, Heaton Road, Newcastle-upon-Tyne.
1861. *STONEY, GEORGE JOHNSTONE, M.A., D.Sc., F.R.S., M.R.I.A. (Pres. A, 1879). 30 Ledbury Road, Bayswater, W.
1876. §Stopes, Henry. 25 Denning-road, Hampstead, N.W.
1883. ‡Stopes, Mrs. 25 Denning-road, Hampstead, N.W.
1887. *Storey, H. L. Bailrigg, Lancaster.
1884. §Storrs, George H. Gorse Hall, Stalybridge.
1888. *Stothert, Percy K. The Grange, Bradford on Avon, Wilts.
1874. ‡Stott, William. Scar Bottom, Greetland, near Halifax, Yorkshire.
1871. *STRACHEY, Lieut.-General SIR RICHARD, R.E., G.C.S.I., LL.D., F.R.S., F.R.G.S., F.L.S., F.G.S. (Pres. E, 1875; Council, 1871–75). 69 Lancaster-gate, Hyde Park, W.
1881. ‡STRAHAN, AUBREY, M.A., F.G.S. Geological Museum, Jermyn-street, S.W.
1876. ‡*Strain, John. 143 West Regent Street, Glasgow.*
1863. ‡Straker, John. Wellington House, Durham.
1882. ‡Strange, Rev. Cresswell, M.A. Edgbaston Vicarage, Birmingham.
1898. ‡Strangeways, C. Fox. Leicester.
1881. ‡STRANGWAYS, C. FOX, F.G.S. Geological Museum, Jermyn-street, S.W.

1889. ‡Streatfeild, H. S., F.G.S. Ryhope, near Sunderland.
1879. ‡Strickland, Sir Charles W., Bart., K.C.B. Hildenley-road, Malton.
1884. ‡Stringham, Irving. The University, Berkeley, California, U.S.A.
1883. §Strong, Henry J., M.D. Colonnade House, The Steyne, Worthing.
1898. *Strong, W. M. 3 Champion Park, Denmark Hill, S.E.
1887. *Stroud, H., M.A., D.Sc., Professor of Physics in the College of Science, Newcastle-upon-Tyne.
1887. *Stroud, William, D.Sc., Professor of Physics in the Yorkshire College, Leeds.
1878. ‡Strype, W. G. Wicklow.
1876. *Stuart, Charles Maddock. St. Dunstan's College, Catford, S.E.
1872. *Stuart, Rev. Edward A., M.A. 5 Prince's-square, W.
1892. ‡Stuart, Hon. Morton Gray, M.A., F.G.S. 2 Belford Park, Edinburgh.
1884. ‡Stuart, Dr. W. Theophilus. 183 Spadina-avenue, Toronto, Canada.
1893. ‡Stubbs, Arthur G. Sherwood Rise, Nottingham.
1896. ‡Stubbs, Miss. Torrisholme, Aigburth-drive, Sefton Park, Liverpool.
1885. ‡Stump, Edward C. 16 Herbert-street, Moss Side, Manchester.
1897. ‡Stupart, R. F. The Observatory, Toronto, Canada.
1879. *Styring, Robert. 64 Crescent-road, Sheffield.
1891. *Sudborough, Professor J. J., Ph.D., B.Sc. University College of Wales, Aberystwyth.
1898. §Sully, T. N. Avalon House, Priory-road, Tyndall's Park, Clifton, Bristol.
1884. ‡Sumner, George. 107 Stanley-street, Montreal, Canada.
1887. ‡Sumpner, W. E. 37 Pennyfields, Poplar, E.
1888. ‡Sunderland, John E. Bark House, Hatherlow, Stockport.
1883. ‡Sutcliffe, J. S., J.P. Beech House, Bacup.
1873. ‡Sutcliffe, Robert. Idle, near Leeds.
1863. ‡Sutherland, Benjamin John. Thurso House, Newcastle-upon-Tyne.
1886. ‡Sutherland, Hugh. Winnipeg, Manitoba, Canada.
1892. ‡Sutherland, James B. 10 Windsor-street, Edinburgh.
1884 ‡Sutherland, J. C. Richmond, Quebec, Canada.
1862. ‡Sutton, Francis, F.C.S. Bank Plain, Norwich.
1889. ‡Sutton, William. Esbank, Jesmond, Newcastle-upon-Tyne.
1898. §Sutton, William, M.D. 6 Camden-crescent, Dover.
1891. ‡Swainson, George, F.L.S. North Drive, St. Anne's-on-Sea, Lancashire.
1881. ‡Swales, William. Ashville, Holgate Hill, York.
1881. §Swan, Joseph Wilson, M.A., F.R.S. 58 Holland-park, W.
1897. §Swanston, William, F.G.S. Mount Collyer Factory, Belfast.
1879. ‡Swanwick, Frederick. Whittington, Chesterfield.
1887. §Swinburne, James, M.Inst.C.E. 82 Victoria-street, S.W.
1870. *Swinburne, Sir John, Bart. Capheaton Hall, Newcastle-upon-Tyne.
1887. *Swindells, Rupert, F.R.G.S. 22 Oxford Road, Birkdale, Southport.
1890. ‡Swinhoe, Colonel C., F.L.S. Avenue House, Oxford.
1891. ‡Swinnerton, R. W., Assoc.M.Inst.C.E. Bolarum, Dekkan, India.
1873. ‡Sykes, Benjamin Clifford, M.D. St. John's House, Cleckheaton.
1895. ‡Sykes, E. R. 3 Gray's Inn-place, W.C.
1887. *Sykes, George H., M.A., M.Inst.C.E., F.S.A. Glencoe, 64 Elmbourne-road, Tooting Common, S.W.
1896. *Sykes, Mark L., F.R.M.S. Chatleigh House, Limpley Stoke, Bath.
1887. *Sykes, T. H. Cringle House, Cheadle, Cheshire.
1893. ‡Symes, Rev. J. E., M.A. 70 Redcliffe-crescent, Nottingham.
1870. ‡Symes, Richard Glascott, M.A., F.G.S., Geological Survey of Scotland, Sheriff Court-buildings, Edinburgh.

Year of Election.

1885. ‡Symington, Johnson, M.D. Queen's College, Belfast.
1886. ‡Symons, W. H., M.D. (Brux.), M.R.C.P., F.I.C. Guildhall, Bath.

1896. §Tabor, J. M. Holmwood, Haringey Park, Crouch End, N.
1898. ‡Tagart, Francis. 199 Queen's-gate, S.W.
1865. ‡Tailyour, Colonel Renny, R.E. Newmanswalls, Montrose, Forfarshire.
1894. †Takakusu, Jyun, B.A. 17 Worcester-terrace, Oxford.
1890. ‡Tanner, H. W. Lloyd, D.Sc., F.R.S. (Local Sec. 1891), Professor of Mathematics and Astronomy in University College, Cardiff.
1897. ‡Tanner, Professor J. H. Ithaca, New York, U.S.A.
1892. *Tansley, Arthur G. University College, W.C.
1883. *Tapscott, R. Lethbridge, F.R.A.S. 62 Croxteth-road, Liverpool.
1878. ‡Tarpey, Hugh. Dublin.
1861. *Tarratt, Henry W. Broadhayes, Dean Park, Bournemouth.
1857. *Tate, Alexander. Rantalard, Whitehouse, Belfast.
1893. ‡Tate, George, Ph.D. College of Chemistry, Duke-street, Liverpool.
1858. *Tatham, George, J.P. Springfield Mount, Leeds.
1901. §Taylor, Benson. 22 Hayburn Crescent, Partick, Glasgow.
1884. *Taylor, Rev. Charles, D.D. St. John's Lodge, Cambridge.
1887. §Taylor, G. H. Holly House, 235 Eccles New-road, Salford.
1898. ‡Taylor, Lieut.-Colonel G. L. Le M. 6 College-lawn, Cheltenham.
1874. ‡*Taylor, G. P. Students' Chambers, Belfast.*
1887. ‡Taylor, George Spratt. 13 Queen's-terrace, St. John's Wood, N.W.
1881. *Taylor, H. A. 69 Addison-road, Kensington, W.
1884. *Taylor, H. M., M.A., F.R.S. Trinity College, Cambridge.
1882. *Taylor, Herbert Owen, M.D. Oxford-street, Nottingham.
1860. *Taylor, John, M.Inst.C.E., F.G.S. 6 Queen Street Place, E.C.
1881. *Taylor, John Francis. Holly Bank House, York.
1865. ‡Taylor, Joseph. 99 Constitution-hill, Birmingham.
1876. ‡Taylor, Robert. 70 Bath-street, Glasgow.
1899. ‡Taylor, Robert H., M.Inst.C.E. 5 Maison Dieu-road, Dover.
1884. *Taylor, Miss S. Oak House, Shaw, near Oldham.
1881. ‡*Taylor, Rev. S. B., M.A. Whixley Hall, York.*
1883. ‡Taylor, S. Leigh. Birklands, Westcliffe-road, Birkdale, Southport.
1900. §Taylor, T. H. Yorkshire College, Leeds.
1870. ‡Taylor, Thomas. Aston Rowant, Tetsworth, Oxon.
1887. ‡Taylor, Tom. Grove House, Sale, Manchester.
1883. ‡Taylor, William, M.D. 21 Crockherbtown, Cardiff.
1901. §Taylor, William. 57 Sparkenhoe Street, Glasgow.
1895. ‡Taylor, W. A., M.A., F.R.S.E. Royal Scottish Geographical Society, Edinburgh.
1893. ‡Taylor, W. F. Bhootan, Whitehorse-road, Croydon, Surrey.
1894. *Taylor, W. W. 30 Banbury-road, Oxford.
1884. ‡Taylor-Whitehead, Samuel, J.P. Burton Closes, Bakewell.
1901. *Teacher, John H., M.B. 32 Huntley Gardens, Glasgow.
1858. ‡Teale, Thomas Pridgin, M.A., F.R.S. 38 Cookridge-street, Leeds.
1885. ‡Teall, J. J. H., M.A., F.R.S., F.G.S. (Pres. C, 1893; Council 1894–1900), Director-General of the Geological Survey of the United Kingdom. 2 Sussex Gardens, West Dulwich, S.E.
1898. §Tebb, Robert Palmer. Enderfield, Chislehurst, Kent.
1879. ‡Temple, Lieutenant G. T., R.N., F.R.G.S. The Nash, near Worcester.
1880. ‡Temple, The Right Hon. Sir Richard, Bart., G.C.S.I., C.I.E., D.C.L., LL.D., F.R.S., F.R.G.S. (Pres. E, 1882; F, 1884; Council 1884–87). Athenæum Club, S.W.

Year of Election.

1863. ‡Tennant, Henry. Saltwell, Newcastle-upon-Tyne.
1889. ‡Tennant, James. Saltwell, Gateshead.
1894. ‡*Terras, J. A., B.Sc. 40 Findhorn-place, Edinburgh.*
1882. ‡Tetrill, William. 42 St. George's-terrace, Swansea.
1896. *Terry, Rev. T. R., M.A., F.R.A.S. The Rectory, East Ilsley, Newbury, Berkshire.
1892. *Tesla, Nikola. 45 West 27th-street, New York, U.S.A.
1883. ‡Tetley, C. F. The Brewery, Leeds.
1883. ‡Tetley, Mrs. C. F. The Brewery, Leeds.
1882. *THANE, GEORGE DANCER, Professor of Anatomy in University College, Gower-street, W.C. Hemmet, St. John's Road, Harrow.
1889. ‡Thetford, The Right Rev. A. T. Lloyd, Bishop of, D.D. North Creake Rectory, Fakenham, Norfolk.
1885. ‡Thin, Dr. George. 22 Queen Anne-street, W.
1871. ‡*Thin, James. 7 Rillbank-terrace, Edinburgh.*
1871. ‡THISELTON-DYER, Sir W. T., K.C.M.G., C.I.E., M.A., B.Sc., Ph.D., LL.D., F.R.S., F.L.S. (Pres. D, 1888; Pres. K, 1895; Council 1885–89, 1895–1900). Royal Gardens, Kew.
1870. ‡Thom, Robert Wilson. Lark-hill, Chorley, Lancashire.
1891. ‡Thomas, Alfred, M.P. Pen-y-lan, Cardiff.
1891. ‡Thomas, A. Garrod, M.D., J.P. Clytha Park, Newport, Monmouthshire.
1891. *Thomas, Miss Clara. Penurrig, Builth.
1891. ‡Thomas, Edward. 282 Bute-street, Cardiff.
1891. ‡Thomas, E. Franklin. Dan-y-Bryn, Radyr, near Cardiff.
1869. ‡Thomas, H. D. Fore-street, Exeter.
1875. ‡Thomas, Herbert. Ivor House, Redland, Bristol
1881. ‡THOMAS, J. BLOUNT. Southampton.
1869. ‡Thomas, J. Henwood, F.R.G.S. 86 Breakspear's-road, Brockley, S.E.
1880. *Thomas, Joseph William, F.C.S. 2 Hampstead Hill-mansions, N.W.
1899. *Thomas, Mrs. J. W. 2 Hampstead Hill-mansions, N.W.
1883. ‡Thomas, Thomas H. 45 The Walk, Cardiff.
1898. ‡Thomas, Rev. U. Bristol School Board, Guildhall, Bristol.
1883. ‡Thomas, William. Lan, Swansea.
1886. ‡Thomas, William. 109 Tettenhall-road, Wolverhampton.
1886. ‡Thomason, Yeoville. 9 Observatory-gardens, Kensington, W.
1875. ‡Thompson, Arthur. 12 St. Nicholas-street, Hereford.
1891. *Thompson, Beeby, F.C.S., F.G.S. 67 Victoria-road, Northampton.
1883. ‡Thompson, Miss C. E. Heald Bank, Bowdon, Manchester.
1891. ‡Thompson, Charles F. Penhill Close, near Cardiff.
1882. ‡Thompson, Charles O. Terre Haute, Indiana, U.S.A.
1888. *Thompson, Claude M., M.A., Professor of Chemistry in University College, Cardiff.
1885. ‡THOMPSON, D'ARCY W., B.A., C.B., Professor of Zoology in University College, Dundee.
1896. *Thompson, Edward P. Paulsmoss, Whitchurch, Salop.
1883. *Thompson, Francis. Lynton, Haling Park-road, Croydon.
1891. ‡Thompson, G. Carslake. Park-road, Penarth.
1893. *Thompson, Harry J., M.Inst.C.E., Madras. Care of Messrs. Grindlay & Co., Parliament-street, S.W.
1870. ‡THOMPSON, Sir HENRY, Bart. 35 Wimpole-street, W.
1883. *Thompson, Henry G., M.D. 86 Lower Addiscombe-road, Croydon.
1891. ‡Thompson, Herbert M. Whitley Batch, Llandaff.
1891. ‡Thompson, H. Wolcott. 9 Park-place, Cardiff.

Year of Election.

1883. *THOMPSON, ISAAC COOKE, F.L.S., F.R.M.S. (Local Sec. 1896). 53 Croxteth-road, Liverpool.
1897. ‡Thompson, J. Barclay. 37 St. Giles's, Oxford.
1891. ‡Thompson, J. Tatham, M.B. 23 Charles-street, Cardiff.
1861. *THOMPSON, JOSEPH. Riversdale, Wilmslow, Cheshire.
1876. *Thompson, Richard. Dringcote, The Mount, York.
1883. ‡Thompson, Richard. Bramley Mead, Whalley, Lancashire.
1876. ‡THOMPSON, SILVANUS PHILLIPS, B.A., D.Sc., F.R.S., F.R.A.S. (Council 1897–99), Principal and Professor of Physics in the City and Guilds of London Technical College, Finsbury, E.C.
1883. *Thompson, T. H. Redlynch House, Green Walk, Bowdon, Cheshire.
1896. *THOMPSON, W. H., M.D., Professor of Physiology in Queen's College, Belfast.
1896. ‡Thompson, W. P. 6 Lord-street, Liverpool.
1867. ‡Thoms, William. Magdalen-yard-road, Dundee.
1894. ‡THOMSON, ARTHUR, M.A., M.D., Professor of Human Anatomy in the University of Oxford. Exeter College, Oxford.
1889. *Thomson, James, M.A. 22 Wentworth-place, Newcastle-upon-Tyne.
1891. ‡Thomson, John. 70A Grosvenor-street, W.
1896. ‡Thomson, John. 3 Derwent-square, Stonycroft, Liverpool.
1890. §THOMSON, Professor J. ARTHUR, M.A., F.R.S.E. Castleton House, Old Aberdeen.
1883. ‡THOMSON, J. J., M.A., D.Sc., F.R.S. (Pres. A, 1896; Council 1893–95), Professor of Experimental Physics in the University of Cambridge. 6 Scrope-terrace, Cambridge.
1871. *THOMSON, JOHN MILLAR, LL.D., F.R.S. (Council 1895–1901), Professor of Chemistry in King's College, London. 85 Addison-road, W.
1901. §Thomson, Dr. J. I. Kilpatrick. 148 Norfolk Street, Glasgow.
1874. §THOMSON, WILLIAM, F.R.S.E., F.C.S. Royal Institution, Manchester.
1880. §Thomson, William J. Ghyllbank, St. Helens.
1897. ‡Thorburn, James, M.D. Toronto, Canada.
1871. ‡Thornburn, Rev. David, M.A. 1 John's-place, Leith.
1887. ‡Thornton, John. 3 Park-street, Bolton.
1867. ‡Thornton, Sir Thomas. Dundee.
1898. §Thornton, W. M. The Durham College of Science, Newcastle-on-Tyne.
1883. ‡Thorowgood, Samuel. Castle-square, Brighton.
1881. ‡Thorp, Fielden. Blossom-street, York.
1881. *Thorp, Josiah. Undercliffe, Holmfirth.
1898. §Thorp, Thomas. Moss Bank, Whitefield, Manchester.
1898. ‡Thorpe, Jocelyn Field, Ph.D. Owens College, Manchester.
1871. ‡THORPE, T. E., C.B., Ph.D., LL.D., F.R.S., F.R.S.E., V.P.C.S. (Pres. B, 1890; Council 1886–92), Principal of the Government Laboratories, Clement's Inn-passage, W.C.
1883. §Threlfall, Henry Singleton, J.P. 1 London-street, Southport.
1899. §THRELFALL, RICHARD, M.A., F.R.S. 259 Hagley-road, Birmingham.
1896. §Thrift, Professor William Edward. 80 Grosvenor-square, Rathmines, Dublin.
1868. ‡THUILLIER, General Sir H. E. L., R.A., C.S.I., F.R.S., F.R.G.S. Tudor House, Richmond Green, Surrey.
1889. ‡Thys, Captain Albert. 9 Rue Briderode, Brussels.
1870. ‡Tichborne, Charles R. C., LL.D., F.C.S., M.R.I.A. Apothecaries' Hall of Ireland, Dublin.
1873. *TIDDEMAN, R. H., M.A., F.G.S. Geological Survey Office, 28 Jermyn-street, S.W.

Year of
Election.

1874. ‡Tilden, William A., D.Sc., F.R.S., Treas.C.S. (Pres. B, 1888, Council 1898–), Professor of Chemistry in the Royal College of Science, South Kensington, London. The Oaks, Northwood, Middlesex.
1883. ‡Tillyard, A. I., M.A. Fordfield, Cambridge.
1883. ‡Tillyard, Mrs. Fordfield, Cambridge.
1865. ‡Timmins, Samuel, J.P., F.S.A. Spring Hill, Arley, Coventry.
1896. §Timmis, Thomas Sutton. Cleveley, Allerton, Yorkshire.
1899. ‡Tims, H. W. Marett, M.D., F.L.S. 19 Lyndewode Road, Cambridge.
1900. §Tocher, J. F., F.I.C. 5 Chapel Street, Peterhead, N.B.
1876. ‡Todd, Rev. Dr. Tudor Hall, Forest Hill, S.E.
1891. ‡Todd, Richard Rees. Portuguese Consulate, Cardiff.
1897. ‡Todhunter, James. 85 Wellesley-street, Toronto, Canada.
1889. §Toll, John M. 49 Newsham-drive, Liverpool.
1857. ‡Tombe, Rev. Canon. Glenealy, Co. Wicklow.
1888. ‡Tomkins, Rev. Henry George. Park Lodge, Weston-super-Mare.
1896. ‡Toms, Frederick. 1 Ambleside-avenue, Streatham, S.W.
1887. ‡Tonge, James, F.G.S. Woodbine House, West Houghton, Bolton.
1865. ‡Tonks, Edmund, B.C.L. Packwood Grange, Knowle, Warwickshire.
1873. *Tookey, Charles, F.C.S. Royal School of Mines, Jermyn-street, S.W.
1875. ‡Torr, Charles Hawley. St. Alban's Tower, Mansfield-road, Sherwood, Nottingham.
1884. *Torrance, Rev. Robert, D.D. Guelph, Ontario, Canada.
1873. ‡Townend, W. H. Heaton Hall, Bradford, Yorkshire.
1875. ‡Townsend, Charles. St. Mary's, Stoke Bishop, Bristol.
1901. §Townsend, Professor John S. New College, Oxford.
1861. ‡Townsend, William. Attleborough Hall, near Nuneaton.
1877. ‡Tozer, Henry. Ashburton.
1876. *Trail, J. W. H., M.A., M.D., F.R.S., F.L.S., Regius Professor of Botany in the University of Aberdeen.
1883. ‡Traill, A., M.D., LL.D. Ballylough, Bushmills, Ireland.
1870. ‡Traill, William A. Giant's Causeway Electric Tramway, Portrush, Ireland.
1868. ‡Traquair, Ramsay H., M.D., LL.D., F.R.S., F.G.S. (Pres. D, 1900), Keeper of the Natural History Collections, Museum of Science and Art, Edinburgh.
1891. ‡Trayes, Valentine. Maindell Hall, Newport, Monmouthshire.
1884. ‡Trechmann, Charles O., Ph.D., F.G.S. Hartlepool.
1868. ‡Trehane, John. Exe View Lawn, Exeter.
1891. ‡Treharne, J. Ll. 92 Newport-road, Cardiff.
Trench, F. A. Newlands House, Clondalkin, Ireland.
1887. *Trench-Gascoigne, Mrs. F. R. Parlington, Aberford, Leeds.
1883. ‡Trendell, Edwin James, J.P. Abbey House, Abingdon, Berks.
1884. ‡Trenham, Norman W. 18 St. Alexis-street, Montreal, Canada.
1884. ‡Tribe, Paul C. M. 44 West Oneida-street, Oswego, New York, U.S.A.
1879. ‡Trickett, F. W. 12 Old Haymarket, Sheffield.
1871. ‡Trimen, Roland, M.A., F.R.S., F.L.S., F.Z.S. 11 Dorset Square, N.W.
1860. §Tristram, Rev. Henry Baker, D.D., LL.D., F.R.S., Canon of Durham. The College, Durham.
1884. *Trotter Alexander Pelham. 8 Richmond Terrace, Whitehall, S.W.
1885. §Trotter, Coutts, F.G.S., F.R.G.S. 10 Randolph-crescent, Edinburgh.
1891. ‡Trounce, W. J. 67 Newport-road, Cardiff.
1887. *Trouton, Frederick T., M.A., D.Sc., F.R.S. University College, W.C.

Year of Election.

1898. §Trow, Albert Howard. Glanhafren, 50 Clive Road, Penarth.
1896. ‡Truell, Henry Pomeroy, M.B., F.R.C.S.I. Clonmannon, Ashford, Co. Wicklow.
1885. *Tubby, A. H., F.R.C.S. 25 Weymouth-street, Portland-place, W.
1847. *Tuckett, Francis Fox. Frenchay, Bristol.
1888. ‡Tuckett, William Fothergill, M.D. 18 Daniel-street, Bath.
1871. ‡Tuke, Sir J. Batty, M.D., M.P. Cupar, Fifeshire.
1883. ‡TUPPER, The Hon. Sir CHARLES, Bart., G.C.M.G., C.B. Ottawa, Canada.
1892. ‡Turnbull, Alexander R. Ormiston House, Hawick.
1855. ‡Turnbull, John. 37 West George-street, Glasgow.
1901. §Turnbull, Robert. Joppa, Edinburgh.
1901. §Turner, A. Crosbie. 65 Bath Street, Glasgow.
1893. §TURNER, DAWSON, M.B. 37 George-square, Edinburgh.
1882. ‡Turner, G. S. Pitcombe, Winchester-road, Southampton.
1883. ‡Turner, Mrs. G. S. Pitcombe, Winchester-road, Southampton.
1894. *TURNER, H. H., M.A., B.Sc., F.R.S., F.R.A.S., Professor of Astronomy in the University of Oxford. The Observatory, Oxford.
1886. *TURNER, THOMAS, A.R.S.M., F.C.S., F.I.C. Ravenhurst, Rowley Park, Stafford.
1863. *TURNER, Sir WILLIAM, K.C.B., LL.D., D.C.L., F.R.S., F.R.S.E. (PRESIDENT, 1900; Pres. H, 1889, 1897), Professor of Anatomy in the University of Edinburgh. 6 Eton-terrace, Edinburgh.
1893. ‡TURNEY, Sir JOHN, J.P. Alexandra Park, Nottingham.
1890 *Turpin, G. S., M.A., D.Sc. High School, Nottingham.
1886. *Twigg, G. H. 56 Claremont-road, Handsworth, Birmingham.
1898. ‡Twiggs, H. W. 65 Victoria-street, Bristol.
1899. §Twisden, John R., M.A. 14 Gray's Inn-square, W.C.
1888. ‡Tyack, Llewelyn Newton. University College, Bristol.
1865. §TYLOR, EDWARD BURNETT, D.C.L., LL.D., F.R.S. (Pres. H, 1884; Council 1896–), Professor of Anthropology, and Keeper of the University Museum, Oxford.
1883. ‡Tyrer, Thomas, F.C.S. Stirling Chemical Works, Abbey-lane, Stratford, E.
1897. ‡Tyrrell, J. B., M.A., B.Sc. Ottawa, Canada.
1861. **Tysoe, John. Heald-road, Bowdon, near Manchester.*

1884. *Underhill, G. E., M.A. Magdalen College, Oxford.
1888. ‡Underhill, H. M. 7 High-street, Oxford.
1886. ‡Underhill, Thomas, M.D. West Bromwich.
1885. §Unwin, Howard. 1 Newton-grove, Bedford Park, Chiswick, W.
1883. §Unwin, John. Eastcliffe Lodge, Southport.
1876. *UNWIN, W. C., F.R.S., M.Inst.C.E. (Pres. G, 1892; Council, 1892–99), Professor of Engineering at the Central Institution of the City and Guilds of London Institute. 7 Palace-gate Mansions, Kensington, W.
1887. ‡Upton, Francis R. Orange, New Jersey, U.S.A.
1872. ‡Upward, Alfred. 150 Holland-road, W.
1876. ‡Ure, John F. 6 Claremont-terrace, Glasgow.
1866. ‡Urquhart, William W. Rosebay, Broughty Ferry, by Dundee.
1898. ‡Usher, Thomas. 3 Elmgrove-road, Cotham, Bristol.
1880. ‡USSHER, W. A. E., F.G.S. 28 Jermyn-street, S.W.

1885. ‡Vachell, Charles Tanfield, M.D. 38 Charles-street, Cardiff.
1896. ‡Vacher, Francis. 7 Shrewsbury-road, Birkenhead.
1887. *Valentine, Miss Anne. The Elms, Hale, near Altrincham.

1888. ‡Vallentin, Rupert. 18 Kimberley-road, Falmouth.
1884. ‡Van Horne, Sir W. C., K.C.M.G. Dorchester-street West, Montreal, Canada.
1883. *Vansittart, The Hon. Mrs. A. A. Haywood House, Oaklands-road, Bromley, Kent.
1868. ‡Varley, Frederick H., F.R.A.S. Mildmay Park Works, Mildmay-avenue, Stoke Newington, N.
1865. *VARLEY, S. ALFRED. Arrow Works, Jackson Road, Holloway, N.
1870. ‡Varley, Mrs. S. A. 5 Gayton-road, Hampstead, N.W.
1869. ‡Varwell, P. 2 Pennsylvania Park, Exeter.
1884. †Vasey, Charles. 112 Cambridge-gardens, W.
1895. §Vaughan, D. T. Gwynne. Howry Hall, Llandrindod, Radnorshire.
1887. *VAUGHAN, His Eminence Cardinal. Carlisle-place, Westminster, S.W.
1875. †Vaughan, Miss. Burlton Hall, Shrewsbury.
1883. ‡Vaughan, William. 42 Sussex-road, Southport.
1881. §VELEY, V. H., M.A., F.R.S., F.C.S. 20 Bradmore-road, Oxford.
1873. *VERNEY, Sir EDMUND H., Bart., F.R.G.S. Claydon House, Winslow, Bucks.
1883. *Verney, Lady. Claydon House, Winslow, Bucks.
1883. ‡VERNON, H. H., M.D. (Local Sec. 1883). York-road, Birkdale, Southport.
1896. *Vernon, Thomas T. Wyborne Gate, Birkdale, Southport.
1896. *Vernon, William. Tean Hurst, Tean, Stoke-upon-Trent.
1864. *VICARY, WILLIAM, F.G.S. The Priory, Colleton-crescent, Exeter.
1890. *Villamil, Lieut.-Colonel R. de, R.E. Care of Messrs. Cox & Co., 16 Charing Cross, S.W.
1899. *VINCENT, SWALE, M.B. Physiological Laboratory, University College, Cardiff.
1883. *VINES, SYDNEY HOWARD, M.A., D.Sc., F.R.S., F.L.S. (Pres. K, 1900; Council, 1894–97), Professor of Botany in the University of Oxford. Headington Hill, Oxford.
1891. ‡Vivian, Stephen. Llantrisant.

1886. *Wackrill, Samuel Thomas, J.P. 38 Portland Street, Leamington.
1860. ‡Waddingham, John. Guiting Grange, Winchcombe, Gloucestershire.
1900. ‡Waddington, Dr. C. E. 2 Marlborough Road, Manningham, Bradford.
1890. ‡Wadsworth, G. H. 3 Southfield-square, Bradford, Yorkshire.
1888. ‡Wadworth, H. A. Breinton Court, near Hereford.
1890. §WAGER, HAROLD W. T. Arnold House, Bass Street, Derby.
1900. ‡Wagstaff, C. J. L., B.A. 8 Highfield Place, Manningham, Bradford.
1896. ‡*Wailes, Miss Ellen. Woodmead, Groombridge, Sussex.*
1891. ‡Wailes, T. W. 23 Richmond-road, Cardiff.
1884. ‡Wait, Charles E., Professor of Chemistry in the University of Tennessee. Knoxville, Tennessee, U.S.A.
1886. †Waite, J. W. The Cedars, Bestcot, Walsall.
1870. ‡WAKE, CHARLES STANILAND. Welton, near Brough, East Yorkshire.
1892. ‡*Walcot, John. 50 Northumberland-street, Edinburgh.*
1884. †Waldstein, Professor C., M.A., Ph.D. King's College, Cambridge.
1891. ‡Wales, H. T. Pontypridd.
1891. ‡Walford, Edward, M.D. Thanet House, Cathedral-road, Cardiff.
1894. ‡WALFORD, EDWIN A., F.G.S. West Bar, Banbury.
1882. *Walkden, Samuel, F.R.Met.S. Downside, Whitchurch, Tavistock.
1885. ‡Walker, Mr. Baillie. 52 Victoria-street, Aberdeen.
1893. §Walker, Alfred O., F.L.S. Ulcombe Place, Maidstone, Kent.

Year of Election.

1890. §Walker, A. Tannett. The Elms, Weetwood, Leeds.
1901. *Walker, Archibald, M.A., F.I.C. 8 Crown Terrace, Glasgow.
1897. *WALKER, B. E., F.G.S. (Local Sec. 1897). Canadian Bank of Commerce, Toronto.
1883. ‡Walker, Mrs. Emma. 13 Lendal, York.
1883. ‡Walker, E. R. Pagefield Ironworks, Wigan.
1891. §Walker, Frederick W. Tannett. Carr Manor, Meanwood, Leeds.
1897. ‡Walker, George Blake. Tankersley Grange, near Barnsley.
1894. *WALKER, G. T., M.A. Trinity College, Cambridge.
1866. ‡Walker, H. Westwood, Newport, by Dundee.
1896. ‡Walker, Horace. Belvidere-road, Prince's Park, Liverpool.
1890. ‡Walker, Dr. James. 19 Springfield, Dundee.
1894. *WALKER, JAMES, M.A. 30 Norham-gardens, Oxford.
1866. *WALKER, J. FRANCIS, M.A., F.G.S., F.L.S. 45 Bootham, York.
1886. *Walker, Major Philip Billingsley. 16 Llandaff Street, Waverley, Sydney, New South Wales.
1866. ‡Walker, S. D. 38 Hampden-street, Nottingham.
1884. ‡Walker, Samuel. Woodbury, Sydenham Hill, S.E.
1888. ‡Walker, Sydney F. Bloomfield Crescent, Bath.
1887. ‡Walker, T. A. 15 Great George-street, S.W.
1883. ‡Walker, Thomas A. 66 Leyland-road, Southport.
Walker, William. 47 Northumberland-street, Edinburgh.
1895. §WALKER, WILLIAM G., A.M.Inst.C.E. 47 Victoria-street, S.W.
1896. §Walker, Colonel William Hall, M.P. Gateacre, Liverpool.
1896. ‡Walker, W. J. D. Lawrencetown, Co. Down, Ireland.
1883. ‡Wall, Henry. 14 Park-road, Southport.
1863. ‡WALLACE, ALFRED RUSSEL, D.C.L., F.R.S., F.L.S., F.R.G.S. (Pres. D, 1876; Council 1870–72). Corfe View, Parkstone, Dorset.
1897. ‡Wallace, Chancellor. Victoria University, Toronto, Canada.
1892. ‡Wallace, Robert W. 14 Frederick-street, Edinburgh.
1901. §Wallace, James Sim, M.D., D.Sc. 15 Penrhyn Road, Kingston-on-Thames.
1901. §Wallace, Wm., M.A., M.B. 25 Newton Place, Glasgow.
1887. *WALLER, AUGUSTUS D., M.D., F.R.S. Weston Lodge, 16 Grove End-road, N.W.
1889. *Wallis, Arnold J., M.A. 5 Belvoir-terrace, Cambridge.
1895. ‡WALLIS, E. WHITE, F.S.S. Sanitary Institute, Parkes Museum, Margaret-street, W.
1883. ‡Wallis, Rev. Frederick. Caius College, Cambridge.
1884. ‡Wallis, Herbert. Redpath-street, Montreal, Canada.
1886. ‡Wallis, Whitworth, F.S.A. Chevening, Montague-road, Edgbaston, Birmingham.
1894. *WALMISLEY, A. T., M.Inst.C.E. Engineer's Office, Dover Harbour.
1887. ‡Walmsley, J. Monton Lodge, Eccles, Manchester.
1891. §Walmsley, R. M., D.Sc. Northampton Institute, Clerkenwell, E.C.
1895. §WALSINGHAM, The Right Hon. Lord, LL.D., F.R.S. Merton Hall, Thetford.
1881. ‡Walton, Thomas, M.A. Oliver's Mount School, Scarborough.
1884. ‡Wanless, John, M.D. 88 Union-avenue, Montreal, Canada.
1887. ‡WARD, A. W., M.A., Litt.D. Master of Peterhouse, Cambridge.
1881. §Ward, George, F.C.S. Buckingham-terrace, Headingley, Leeds.
1879. ‡WARD, H. MARSHALL, D.Sc., F.R.S., F.L.S. (Pres. K, 1897; Council 1890–97), Professor of Botany, University of Cambridge. New Museums, Cambridge.
1890. ‡Ward, Alderman John. Moor Allerton House, Leeds.
1874. §Ward, John, J.P., F.S.A. Lenoxvale, Belfast.

Year of
Election.
1887. ‡WARD, JOHN, F.G.S. 23 Stafford-street, Longton, Staffordshire.
1857. ‡Ward, John S. Prospect Hill, Lisburn, Ireland.
1880. *Ward, J. Wesney. 4 Chepstow Mansions, Chepstow Place, Bayswater, W.
1884. *Ward, John William. Newstead, Halifax.
1887. ‡Ward, Thomas. Brookfield House, Northwich.
1882. ‡Ward, William. Cleveland Cottage, Hill-lane, Southampton.
1901. §Wardlaw, Alexander. 21 Hamilton Drive, Glasgow.
1867. ‡Warden, Alexander J. 23 Panmure-street, Dundee.
1858. ‡Wardle, Sir Thomas, F.G.S. St. Edward-street, Leek, Staffordshire.
1884. ‡Wardwell, George J. 31 Grove-street, Rutland, Vermont, U.S.A.
1887. *Waring, Richard S. Standard Underground Cable Co., 16th-street, Pittsburg, Pennsylvania, U.S.A.
1878. ‡WARINGTON, ROBERT, F.R.S., F.C.S. High Bank, Harpenden, St. Albans, Herts.
1882. ‡*Warner, F. I., F.L.S. 20 Hyde Street, Winchester.*
1884. *Warner, James D. 199 Baltic-street, Brooklyn, U.S.A.
1896. †Warrand, Major-General, R.E. Westhorpe, Southwell, Middlesex.
1875. ‡*Warren, Algernon. Downgate, Portishead.*
1887. ‡WARREN, Lieut.-General Sir CHARLES, R.E., K.C.B., G.C.M.G., F.R.S., F.R.G.S. (Pres. E, 1887). Athenæum Club, S.W.
1898. ‡Warrington, Arthur W. University College, Aberystwith.
1893. ‡Warwick, W. D. Balderton House, Newark-on-Trent.
1875. *WATERHOUSE, Major-General J. Oak Lodge, Court-road, Eltham, Kent.
1870. ‡Waters, A. T. H., M.D. 60 Bedford-street, Liverpool.
1900. §Waterston, David. 16 Merchison Terrace, Edinburgh.
1892. ‡Waterston, James H. 37 Lutton-place, Edinburgh.
1875. ‡Watherston, Rev. Alexander Law, M.A., F.R.A.S. The Grammar School, Hinckley, Leicestershire.
1884. ‡Watson, A. G., D.C.L. Uplands, Wadhurst, Sussex.
1901. §Watson, Arnold Thomas, F.L.S. Southwold, Tapton Crescent Road, Sheffield.
1886. *Watson, C. J. Alton Cottage, Botteville Road, Acock's Green, Birmingham.
1883. ‡Watson, C. Knight, M.A. 49 Bedford-square, W.C.
1892. §Watson, G., Assoc.M.Inst.C.E. 21 Springfield-mount, Leeds.
1885. ‡Watson, Deputy Surgeon-General G. A. Hendre, Overton Park, Cheltenham.
1882. ‡WATSON, Rev. HENRY W., D.Sc., F.R.S. The Rectory, Berkeswell, Coventry.
1884. ‡Watson, John. Queen's University, Kingston, Ontario, Canada.
1889. ‡Watson, John, F.I.C. P.O. Box 317, Johannesburg, South Africa.
1863. ‡Watson, Joseph. Bensham-grove, Gateshead.
1863. ‡Watson, R. Spence, LL.D., F.R.G.S. Bensham-grove, Gateshead.
1867. ‡Watson, Thomas Donald. 16 St. Mary's-road, Bayswater, W.
1894. *WATSON, W., B.Sc., F.R.S. 7 Upper Cheyne-row, S.W.
1892. §Watson, William, M.D. Waverley House, Slateford, Midlothian.
1879. *WATSON, WILLIAM HENRY, F.C.S., F.G.S. Steelfield Hall, Gosforth, Cumberland.
1884. ‡Watt, D. A. P. 284 Upper Stanley-street, Montreal, Canada.
1901. §Watt, Henry Anderson. Ardenslate House, Kern, Argyllshire.
1869. ‡Watt, Robert B. E. Ashley-avenue, Belfast.
1888. ‡WATTS, B. H. (Local Sec. 1888). 10 Rivers-street, Bath.
1875. *WATTS, JOHN, B.A., D.Sc. Merton College, Oxford.
1884. *Watts, Rev. Canon Robert R. Stourpaine Vicarage, Blandford.

Year of Election.

1870. §Watts, William, F.G.S. Little Don Waterworks, Langsett, near Penistone.
1896. ‡Watts, W. H. Elm Hall, Wavertree, Liverpool.
1873. *WATTS, W. MARSHALL, D.Sc. Giggleswick Grammar School, and Carrholme, Stackhouse, near Settle.
1883. *WATTS, W. W., M.A., Sec. G.S., Assistant Professor of Geology in the University, Birmingham. Holm Wood, Bracebridge Road Sutton Coalfield.
1891. ‡Waugh, James. Higher Grade School, 110 Newport-road, Cardiff.
1869. ‡Way, Samuel James. Adelaide, South Australia.
1883. ‡Webb, George. 5 Tenterden-street, Bury, Lancashire.
1871. ‡Webb, Richard M. 72 Grand-parade, Brighton.
1890. ‡*Webb, Sidney. 4 Park-village East, N.W.*
1886. ‡WEBBER, Major-General C. E., C.B., M.Inst.C.E. 17 Egerton-gardens, S.W.
1891. §Webber, Thomas. The Laurels, 83 Newport Road, Penarth, Cardiff.
1859. ‡Webster, John. Edgehill, Aberdeen.
1884. *Wedekind, Dr. Ludwig, Professor of Mathematics at Karlsruhe. Jahnstrasse 5, Karlsruhe.
1889. ‡Weeks, John G. Bedlington.
1890. *WEISS, F. ERNEST, B.Sc., F.L.S., Professor of Botany in Owens College, Manchester.
1886. ‡Weiss, Henry. Westbourne-road, Birmingham.
1865. ‡Welch, Christopher, M.A. United University Club, Pall Mall East, S.W.
1894. ‡Weld, Miss. Conal More, Norham-gardens, Oxford.
1876. *WELDON, Professor W. F. R., M.A., F.R.S., F.L.S. (Pres. D, 1898). The Museum, Oxford.
1880. *Weldon, Mrs. Merton Lea, Oxford.
1897. ‡Welford, A. B., M.B. Woodstock, Ontario, Canada.
1881. §Wellcome, Henry S. Snow Hill Buildings, E.C.
1879. §WELLS, CHARLES A., A.I.E.E. 219 High-street, Lewes.
1881. §Wells, Rev. Edward, M.A. West Dean Rectory, Salisbury.
1894. ‡Wells, J. G. Selwood House, Shobnall-street, Burton-on-Trent.
1883. ‡Welsh, Miss. Girton College, Cambridge.
1881. *Wenlock, The Right Hon. Lord. Escrick Park, Yorkshire.
Wentworth, Frederick W. T. Vernon. Wentworth Castle, near Barnsley, Yorkshire.
1864. *Were, Anthony Berwick. Roslyn, Walland's Park, Lewes.
1886. *Wertheimer, Julius, B.A., B.Sc., F.C.S., Principal of and Professor of Chemistry in the Merchant Venturers' Technical College, Bristol.
1865. ‡Wesley, William Henry. Royal Astronomical Society, Burlington House, W.
1853. ‡West, Alfred. Holderness-road, Hull.
1898. ‡West, Charles D. Imperial University, Tokyo, Japan.
1853. †West, Leonard. Summergangs Cottage, Hull.
1900. §West, William, F.L.S. 26 Woodville Terrace, Horton Lane, Bradford.
1897. ‡Western, Alfred E. 36 Lancaster-gate, W.
1882. *Westlake, Ernest, F.G.S. Vale Lodge, Vale of Health, Hampstead, N.W.
1882. ‡Westlake, Richard. Portswood, Southampton.
1882. †WETHERED, EDWARD B., F.G.S. 4 St. Margaret's-terrace, Cheltenham.
1900. §Wethey, E. R., M.A., F.R.G.S. 5 Cunliffe Villas, Manningham, Bradford.

Year of Election.

1885. *WHARTON, Admiral Sir W. J. L., K.C.B., R.N., F.R.S., F.R.A.S., F.R.G.S. (Pres. E, 1894; Council 1890–91), Hydrographer to the Admiralty. Florys, Prince's-road, Wimbledon Park, Surrey.
1853. ‡Wheatley, E. B. Cote Wall, Mirfield, Yorkshire.
1884. ‡Wheeler, Claude L., M.D. 251 West 52nd-street, New York City, U.S.A.
1878. *Wheeler, W. H., M.Inst.C.E. Wyncote, Boston, Lincolnshire.
1888. §Whelen, John Leman. 18 Frognal, Hampstead, N.W.
1883. ‡*Whelpton, Miss K. Newnham College, Cambridge.*
1893. *WHETHAM, W. C. D., M.A., F.R.S. Trinity College, Cambridge.
1888. *Whidborne, Miss Alice Maria. Charanté, Torquay.
1888. *Whidborne, Miss Constance Mary. Charanté, Torquay.
1879. *WHIDBORNE, Rev. GEORGE FERRIS, M.A., F.G.S. The Priory, Westbury-on-Trym, near Bristol.
1898. *Whipple, Robert S. Scientific Instrument Company, Cambridge.
1874. ‡Whitaker, Henry, M.D. Fortwilliam Terrace, Belfast.
1883. *Whitaker, T. Walton House, Burley-in-Wharfedale.
1859. *WHITAKER, WILLIAM, B.A., F.R.S., F.G.S. (Pres. C, 1895; Council 1890–96.) Freda, Campden-road, Croydon.
1884. ‡Whitcher, Arthur Henry. Dominion Lands Office, Winnipeg, Canada.
1880. ‡Whitcombe, E. B. Borough Asylum, Winson Green, Birmingham.
1897. ‡Whitcombe, George. The Wotton Elms, Wotton, Gloucester.
1886. ‡White, Alderman, J.P. Sir Harry's-road, Edgbaston, Birmingham.
1876. ‡White, Angus. Easdale, Argyllshire.
1886. ‡White, A. Silva. 47 Clanricarde-gardens, W.
1898. ‡White, George. Clare-street House, Bristol.
1882. ‡White, Rev. George Cecil, M.A. Nutshalling Rectory, Southampton.
1885. *White, J. Martin. Balruddery, Dundee.
1873. ‡White, John. Medina Docks, Cowes, Isle of Wight.
1883. ‡White, John Reed. Rossall School, near Fleetwood.
1865. ‡White, Joseph. 6 Southwell-gardens, S.W.
1895. ‡White, Philip J., M.B., Professor of Zoology in University College, Bangor, North Wales.
1884. ‡White, R. 'Gazette' Office, Montreal, Canada.
1898. ‡White, Samuel. Clare-street House, Bristol.
1859. ‡White, Thomas Henry. Tandragee, Ireland.
1877. *White, William. 20 Hillersdon Avenue, Church Road, Barnes, S.W.
1886. *White, William. The Ruskin Museum, Sheffield.
1897. *WHITE, Sir W. H., K.C.B., F.R.S. (Pres. G, 1899; Council 1897-1900). 30 Roland Gardens, S.W.
1883. ‡Whitehead, P. J. 6 Cross-street, Southport.
1893. §Whiteley, R. Lloyd, F.C.S., F.I.C. 80 Beeches-road, West Bromwich.
1881. ‡Whitfield, John, F.C.S. 113 Westborough, Scarborough.
1852. ‡*Whitla, Valentine. Beneden, Belfast.*
1900. §Whitley, E. N. Heath Royde, Halifax.
1891. §Whitmell, Charles T., M.A., B.Sc. Invermay, Headingley, Leeds.
1896. §Whitney, Colonel C. A. The Grange, Fulwood Park, Liverpool.
1897. ‡WHITTAKER, E. T., M.A. Trinity College, Cambridge.
1901. §Whitton, James. City Chambers, Glasgow.
1857. *WHITTY, Rev. JOHN IRWINE, M.A., D.C.L., LL.D. Alpha Villa, Southwood, Ramsgate.
1887. ‡Whitwell, William. Overdene, Saltburn-by-the-Sea.

Year of Election.

1874. *Whitwill, Mark. 1 Berkeley-square, Clifton, Bristol.
1883. ‡Whitworth, James. 88 Portland-street, Southport.
1870. ‡Whitworth, Rev. W. Allen, M.A. 7 Margaret-street, W.
1892. §Whyte, Peter, M.Inst.C.E. 4 Magdala Crescent, Edinburgh
1897. ‡Wickett, M., Ph.D. 339 Berkeley-street, Toronto, Canada.
1888. ‡Wickham, Rev. F. D. C. Horsington Rectory, Bath.
1865. ‡Wiggin, Sir H., Bart. Metchley Grange, Harborne, Birmingham.
1886. ‡Wiggin, Henry A. The Lea, Harborne, Birmingham.
1896. ‡Wigglesworth, J. County Asylum, Rainhill, Liverpool.
1878. ‡Wigham, John R. Albany House, Monkstown, Dublin.
1889. *WILBERFORCE, Professor L. R., M.A. University College, Liverpool.
1887. ‡Wild, George. Bardsley Colliery, Ashton-under-Lyne.
1887. *WILDE, HENRY, D.Sc., F.R.S. The Hurst, Alderley Edge, Cheshire.
1896. ‡Wildermann, Meyer. 22 Park-crescent, Oxford.
1887. ‡ *Wilkinson, C. H. Slaithwaite, near Huddersfield.*
1900. §Wilkinson, J. B. Dudley Hill, Bradford.
1892. ‡Wilkinson, Rev. J. Frome., M.A. Barley Rectory, Royston, Herts.
1886. *Wilkinson, J. H. Elmhurst Hall, Lichfield.
1879. ‡Wilkinson, Joseph. York.
1887. *Wilkinson, Thomas Read. Vale Bank, Knutsford, Cheshire.
1872. ‡Wilkinson, William. 168 North-street, Brighton.
1890. ‡Willans, J. W. Kirkstall, Leeds.
1872. ‡WILLETT, HENRY (Local Sec. 1872). Arnold House, Brighton.
1894. ‡Willey, Arthur. New Museums, Cambridge.
1891. ‡Williams, Arthur J., M.P. Coedymwstwr, near Bridgend.
1861. *Williams, Charles Theodore, M.A., M.B. 2 Upper Brook-street, Grosvenor-square, W.
1887. ‡Williams, Sir E. Leader, M.Inst.C.E. The Oaks, Altrincham.
1883. *Williams, Edward Starbuck. Ty-ar-y-graig, Swansea.
1861. *Williams, Harry Samuel, M.A., F.R.A.S. 6 Heathfield, Swansea.
1875. *Williams, Rev. Herbert Addams. Llangibby Rectory, near Newport, Monmouthshire.
1883. ‡Williams, Rev. H. Alban, M.A. Christ Church, Oxford.
1888. ‡Williams, James. Bladud Villa, Entry Hill, Bath.
1891. §Williams, J. A. B., M.Inst.C.E. Lingfield Grange, Branksome Park, Bournemouth.
1883. *Williams, Mrs. J. Davies. 3 Lord Street West, Southport.
1887. ‡Williams, J. Francis, Ph.D. Salem, New York, U.S.A.
1888. *Williams, Miss Katharine T. Llandaff House, Pembroke Vale, Clifton, Bristol.
1875. *Williams, M. B. Killay House, Killay, R.S.O.
1901. *Williams, Miss M. F. S. 6 Sloane Gardens, S.W.
1891. ‡Williams, Morgan. 5 Park-place, Cardiff.
1886. ‡Williams, Richard, J.P. Brunswick House, Wednesbury.
1883. ‡Williams, R. Price. 28 Compayne-gardens, West Hampstead, N.W.
1883. ‡Williams, T. H. 21 Strand-street, Liverpool.
1877. *WILLIAMS, W. CARLETON, F.C.S. University College, Sheffield.
1850. *WILLIAMSON, ALEXANDER W., Ph.D., LL.D., D.C.L., F.R.S. (PRESIDENT, 1873; TREASURER, 1874–91; Pres. B, 1863, 1881; Council 1861–72). High Pitfold, Haslemere.
1857. ‡WILLIAMSON, BENJAMIN, M.A., D.C.L., F.R.S. Trinity College, Dublin.
1876. ‡Williamson, Rev. F. J. Ballantrae, Girvan, N.B.
1863. ‡Williamson, John. South Shields.
1895. ‡WILLINK, W. (Local Sec. 1896). 14 Castle-street, Liverpool.

Year of Election.

1895. ‡Willis, John C., M.A., Director of the Royal Botanical Gardens, Ceylon.
1896. ‡WILLISON, J. S. (Local Sec. 1897). Toronto, Canada.
1882.*‡Willmore, Charles. Queenwood College, near Stockbridge, Hants.
1859. *Wills, The Hon. Sir Alfred. Chelsea Lodge, Tite-street, S.W.
1886. ‡Wills, A. W. Wylde Green, Erdington, Birmingham.
1898. ‡Wills, H. H. Barley Wood, Wrington, R.S.O., Somerset.
1899. §Willson, George. The Rosary, Wendover, Tring.
1899. §Willson, Mrs. George. The Rosary, Wendover, Tring.
1886. ‡Wilson, Alexander B. Holywood, Belfast.
1901. §Wilson, A. Belvoir Park, Newtownbreda, Co. Down.
1878. ‡Wilson, Professor Alexander S., M.A., B.Sc. Free Church Manse, North Queensferry.
1876. ‡Wilson, Dr. Andrew. 118 Gilmore-place, Edinburgh.
1894. *Wilson, Charles J., F.I.C., F.C.S. 14 Old Queen-street, Westminster, S.W.
1874. ‡WILSON, Major-General Sir C. W., R.E., K.C.B., K.C.M.G., D.C.L., F.R.S., F.R.G.S. (Pres E, 1874, 1888). The Athenæum Club, S.W.
1876. ‡Wilson, David. 124 Bothwell-street, Glasgow.
1900. *Wilson, Duncan R. Menethorpe, Malton.
1890. ‡Wilson, Edmund. Denison Hall, Leeds.
1863. ‡Wilson, Frederic R. Alnwick, Northumberland.
1847. *Wilson, Frederick. 99 Albany-street, N.W.
1875. ‡WILSON, GEORGE FERGUSSON, F.R.S., F.C.S., F.L.S. Heatherbank, Weybridge Heath, Surrey.
1874. *Wilson, George Orr. 20 Berkeley Street, W.
1863. ‡Wilson, George W. Heron Hill, Hawick, N.B.
1895. ‡Wilson, Dr. Gregg. The University, Edinburgh.
1901. §Wilson, Harold A. Trinity College, Cambridge.
1883. *Wilson, Henry, M.A. Farnborough Lodge, Farnborough, R.S.O., Kent.
1879. ‡Wilson, Henry J. 255 Pitsmoor-road, Sheffield.
1885. ‡Wilson, J. Dove, LL.D. 17 Rubislaw-terrace, Aberdeen.
1890. ‡Wilson, J. Mitchell, M.D. 51 Hall Gate, Doncaster.
1865. ‡WILSON, Ven. Archdeacon JAMES M., M.A., F.G.S. The Vicarage, Rochdale.
1884. ‡Wilson, James S. Grant. Geological Survey Office, Sheriff Court-buildings, Edinburgh.
1896. ‡*Wilson, John H., D.Sc., F.R.S.E., Professor of Botany, Yorkshire College, Leeds.*
1879. ‡Wilson, John Wycliffe. Eastbourne, East Bank-road, Sheffield.
1901. *Wilson, Joseph. Columba Villa, Oban, N.B.
1901. §Wilson, Mrs. Mary R., M.D. Ithaca, New York, U.S.A.
1876. ‡Wilson, R. W. R. St. Stephen's Club, Westminster, S.W.
1847. *Wilson, Rev. Sumner. Preston Candover Vicarage, Basingstoke.
1883. ‡Wilson, T. Rivers Lodge, Harpenden, Hertfordshire.
1861. ‡*Wilson, Thos. Bright. 4 Hope View, Fallowfield, Manchester.*
1892. §Wilson, T. Stacey, M.D. Wyddrington, Edgbaston, Birmingham.
1887. §Wilson, W., jun. Hillocks of Terpersie, by Alford, Aberdeenshire.
1871. *WILSON, WILLIAM E., D.Sc., F.R.S. Daramona House, Streete, Rathowen, Ireland.
1861. *WILTSHIRE, Rev. THOMAS, M.A., D.Sc., F.G.S., F.L.S., F.R.A.S. 25 Granville-park, Lewisham, S.E.
1877. ‡Windeatt, T. W. Dart View, Totnes.
1886. ‡WINDLE, BERTRAM C. A., M.A., M.D., D.Sc., F.R.S., Professor of Anatomy, The University, Birmingham.

Year of Election.

1863. *WINWOOD, Rev. H. H., M.A., F.G.S. (Local Sec. 1864). 11 Cavendish-crescent, Bath.
1888. ‡WODEHOUSE, Right Hon. E. R., M.P. 56 Chester-square, S.W.
1875. ‡WOLFE-BARRY, Sir JOHN, K.C.B., F.R.S., M.Inst.C.E. (Pres. G, 1898; Council, 1899–). 21 Delahay-street, Westminster, S.W.
1883. ‡Wolfenden, Samuel. Cowley Hill, St. Helens, Lancashire.
1898. ‡Wollaston, G. H Clifton College, Bristol.
1884. ‡Womack, Frederick, M.A., B.Sc., Lecturer on Physics and Applied Mathematics at St. Bartholomew's Hospital. Bedford College, Baker-street, W.
1883. ‡Wood, Mrs. A. J. 5 Cambridge-gardens, Richmond, Surrey.
1863. *Wood, Collingwood L. Freeland, Forgandenny, N.B.
1883. ‡Wood, Miss Emily F. Egerton Lodge, near Bolton, Lancashire.
1901. *Wood, Miss Ethel M. 3 Shorncliffe Road, Folkestone.
1875. *Wood, George William Rayner. Singleton, Manchester.
1878. ‡WOOD, Sir H. TRUEMAN, M.A. Society of Arts, John Street, Adelphi, W.C., and 16 Leinster Square, Bayswater, W.
1883. *Wood, J. H. 21 Westbourne Road, Birkdale.
1893. ‡Wood, Joseph T. 29 Muster's-road, West Bridgeford, Nottinghamshire.
1883. ‡Wood, Mrs. Mary. Care of E. P. Sherwood, Esq. Holmes Villa, Rotherham.
1864. ‡Wood, Richard, M.D. Driffield, Yorkshire.
1871. ‡Wood, Provost T. Baileyfield, Portobello, Edinburgh.
1899. *Wood, W. Hoffman. Ben Rhydding, Yorkshire.
1901. *Wood, William James. 38 Cochrane Street, Glasgow.
1872. ‡Wood, William Robert. Carlisle House, Brighton.
1845. *Wood, Rev. William Spicer, M.A., D.D. Waldington, Combe Park, Bath.
1863. *WOODALL, JOHN WOODALL, M.A., F.G.S. 5 Queen's-mansions, Victoria-street, S.W.
1884. ‡Woodbury, C. J. H. 31 Milk-street, Boston, U.S.A.
1883. ‡Woodcock, Herbert S. The Elms, Wigan.
1884. ‡Woodd, Arthur B. Woodlands, Hampstead, N.W.
1890. §WOODHEAD, Professor G. SIMS, M.D. Pathological Laboratory, Cambridge.
1888. *Woodiwiss, Mrs. Alfred. Weston Manor, Birkdale, Lancashire.
1872. *WOODS, EDWARD, M.Inst.C.E. (Pres. G, 1877). 8 Victoria-street, Westminster, S.W.
WOODS, SAMUEL. 1 Drapers'-gardens, Throgmorton-street, E.C.
1887. *WOODWARD, ARTHUR SMITH, LL.D., F.R.S., F.L.S., F.G.S., Keeper of the Department of Geology, British Museum (Natural History), Cromwell-road, S.W.
1869. *WOODWARD, C. J., B.Sc., F.G.S. Municipal Technical School, Suffolk Street, Birmingham.
1886. ‡Woodward, Harry Page, F.G.S. 129 Beaufort-street, S.W.
1866. ‡WOODWARD, HENRY, LL.D., F.R.S., F.G.S. (Pres. C, 1887; Council, 1887–94). 129 Beaufort Street, Chelsea, S.W.
1870. ‡WOODWARD, HORACE B., F.R.S., F.G.S. Geological Museum, Jermyn-street, S.W.
1894. *Woodward, John Harold. 13 Queen Anne's-gate, Westminster, S.W.
1884. *Woolcock, Henry. Rickerby House, St. Bees.
1890. *Woollcombe, Robert Lloyd, M.A., LL.D., F.I.Inst., F.S.S., M.R.I.A., F.R.S.A. (Ireland). 14 Waterloo-road, Dublin.
1877. ‡Woollcombe, Surgeon-Major Robert W. 14 Acre-place, Stoke, Devonport.

Year of
Election.

1883. *Woolley, George Stephen. Victoria Bridge, Manchester.
1856. ‡Woolley, Thomas Smith. South Collingham, Newark.
1874. ‡*Workman, Charles. Ceara, Windsor, Belfast.*
1878. ‡Wormell, Richard, M.A., D.Sc. Roydon, near Ware, Hertfordshire.
1863. *Worsley, Philip J. Rodney Lodge, Clifton, Bristol.
1901. §Worth, J. T. Oakenrod, Rochdale.
1855. *Worthington, Rev. Alfred William, B.A. Old Swinford, Stourbridge.
1856. ‡*Worthy, George S. 2 Arlington Terrace, Mornington Crescent, Hampstead Road, N.W.*
1884. ‡Wragge, Edmund. 109 Wellesley-street, Toronto, Canada.
1896. ‡Wrench, Edward M., F.R.C.S. Park Lodge, Bastow.
1879. ‡Wrentmore, Francis. 34 Holland Villas-road, Kensington, S.W.
1883. *Wright, Rev. Arthur, M.A. Queen's College, Cambridge.
1883. *Wright, Rev. Benjamin, M.A. Sandon Rectory, Chelmsford.
1890. ‡Wright, Dr. C. J. Virginia-road, Leeds.
1857. ‡Wright, E. Perceval, M.A., M.D., F.L.S., M.R.I.A., Professor of Botany and Director of the Museum, Dublin University. 5 Trinity College, Dublin.
1886. ‡Wright, Frederick William. 4 Full-street, Derby.
1884. ‡Wright, Harrison. Wilkes' Barré, Pennsylvania, U.S.A.
1876. ‡Wright, James. 114 John-street, Glasgow.
1865. ‡Wright, J. S. 168 Brearley-street West, Birmingham.
1884. ‡Wright, Professor R. Ramsay, M.A., B.Sc. University College, Toronto, Canada.
1876. ‡Wright, William. 31 Queen Mary-avenue, Glasgow.
1871. ‡Wrightson, Sir Thomas, Bart., M.P., M.Inst.C.E., F.G.S. Neasham Hall, Darlington.
1898. ‡Wrong, Professor George M. The University, Toronto, Canada.
1897. ‡Wyld, Frederick. 127 St. George-street, Toronto, Canada.
1901. §Wylie, Alexander. Birkfield, Johnstone, N.B.
1883. ‡Wyllie, Andrew. Sandown, Southport.
1885. ‡Wyness, James D., M.D. 349 Union-street, Aberdeen.
1871. ‡Wynn, Mrs. Williams. Plas-yn-Cefn, St. Asaph.
1862. ‡Wynne, Arthur Beevor, F.G.S. Geological Survey Office, 14 Hume-street, Dublin.
1899. ‡Wynne, W. P., D.Sc., F.R.S. 10 Selwood Terrace, South Kensington, S.W.

1875. ‡Yabbicom, Thomas Henry. 23 Oakfield-road, Clifton, Bristol.
1901. §Yapp, R. H. Caius College, Cambridge.
*Yarborough, George Cook. Camp's Mount, Doncaster.
1894. *Yarrow, A. F. Poplar, E.
1883. ‡Yates, James. Public Library, Leeds.
1896. ‡Yates, Rev. S. A. Thompson. 43 Phillimore-gardens, S.W.
1887. ‡Yeats, Dr. Chepstow.
1884. ‡Yee, Fung. Care of R. E. C. Fittock, Esq., Shanghai, China.
1877. ‡Yonge, Rev. Duke. Puslinch, Yealmpton, Devon.
1891. ‡Yorath, Alderman T. V. Cardiff.
1884. ‡York, Frederick. 87 Lancaster-road, Notting Hill, W.
1891. §Young, Alfred C., F.C.S. 64 Tyrwhitt-road, St. John's, S.E.
1886. *Young, A. H., M.B., F.R.C.S. (Local Sec. 1887), Professor of Anatomy in Owens College, Manchester.
1884. ‡Young, Sir Frederick, K.C.M.G. 5 Queensberry-place, S.W.
1894. *Young, George, Ph.D. University College, Sheffield.
1884. ‡Young, Professor George Paxton. 121 Bloor-street, Toronto, Canada.

Year of Election.

1876. §YOUNG, JOHN, M.D. (Pres. C, 1876; Local Sec. 1901). 38 Cecil-street, Hillhead, Glasgow.
1876. *Young, John. 2 Montague Terrace, Kelvinside, Glasgow.
1896. ‡Young, J. Denholm. 88 Canning-street, Liverpool.
1885. ‡Young, R. Bruce. 8 Crown-gardens, Dowanhill, Glasgow.
1886. §Young, R. Fisher. New Barnet, Herts.
1901. §Young, Robert M. Rathvurna, Belfast.
1883. *YOUNG, SYDNEY, D.Sc., F.R.S., Professor of Chemistry in University College, Bristol. 10 Windsor-terrace, Clifton, Bristol.
1887. ‡Young, Sydney. 29 Mark-lane, E.C.
1890. ‡Young, T. Graham, F.R.S.E. Westfield, West Calder, Scotland.
1901. §Young, William Andrew. Milburn House, Renfrew.
1868. ‡Youngs, John. Richmond Hill, Norwich.

1886. ‡Zair, George. Arden Grange, Solihull, Birmingham.
1886. ‡Zair, John. Merle Lodge, Moseley, Birmingham.

CORRESPONDING MEMBERS.

Year of Election.

1887. Professor Cleveland Abbe. Weather Bureau, Department of Agriculture, Washington, D.C., U.S.A.
1892. Professor Svante Arrhenius. The University, Stockholm. (Bergsgatan 18).
1881. Professor G. F. Barker. 3909, Locust-street, Philadelphia, U.S.A.
1897. Professor Carl Barus. Brown University, Providence, R.I., U.S.A.
1894. Professor F. Beilstein. 8th Line, No. 17, St. Petersburg.
1894. Professor E. van Beneden. 50 quai des Pêcheurs, Liége, Belgium.
1887. Professor A. Bernthsen, Ph.D. Mannheim, L 11, 4, Germany.
1892. Professor M. Bertrand. 75 rue de Vaugirard, Paris.
1894. Deputy Surgeon-General J. S. Billings. 40 Lafayette Place, New York, U.S.A.
1893. Professor Christian-Bohr. Bredgade 62, Copenhagen, Denmark.
1880. Professor Ludwig Boltzmann. IX/I. Türkenstrasse 3, Vienna.
1887. Professor Lewis Boss. Dudley Observatory, Albany, New York, U.S.A.
1884. Professor H. P. Bowditch, M.D. Harvard Medical School, Boston, Massachusetts, U.S.A.
1890. Professor Dr. L. Brentano. Friedrichstrasse 11, München.
1893. Professor Dr. W. C. Brögger. Universitets Mineralogske Institute, Kristiania, Norway.
1887. Professor J. W. Brühl. Heidelberg.
1884. Professor George J. Brush. Yale University, New Haven, Conn., U.S.A.
1894. Professor D. H. Campbell. Stanford University, Palo Alto, California, U.S.A.
1897. M. C. de Candolle. 3 Cour de St. Pierre, Geneva, Switzerland.
1887. Professor G. Capellini. 65 Via Zamboni, Bologna, Italy.
1887. Hofrath Dr. H. Caro. C. 8, No. 9, Mannheim.
1894. Emile Cartailhac. 5 Rue de la Chaîne, Toulouse, France.
1861. Professor Dr. J. Victor Carus. Universitätstrasse 15, Leipzig.
1901. Professor T. C. Chamberlin. Chicago, U.S.A.
1894. Dr. A. Chauveau. Rue Cuvier 7, Paris.
1887. F. W. Clarke. United States Geological Survey, Washington, U.S.A.
1873. Professor Guido Cora. Via Goito 2, Rome.
1880. Professor Cornu. Rue de Grenelle 9, Paris, VIe arr.
1870. *J. M. Crafts, M.D. L'Ecole des Mines, Paris.*
1876. Professor Luigi Cremona. 5 Piazza S. Pietro in Vincoli, Rome.
1889. W. H. Dall. United States Geological Survey, Washington, D.C., U.S.A.
1901. Dr. Yves Delage. Paris.

Year of Election.

1872. Professor G. Dewalque. 17 rue de la Paix, Liége, Belgium.
1870. Dr. Anton Dohrn, D.C.L. Naples.
1890. Professor V. Dwelshauvers-Dery. 4 Quai Marcellis, Liége, Belgium.
1876. Professor Alberto Eccher. Florence.
1894. Professor Dr. W. Einthoven. Leiden, Netherlands.
1892. Professor F. Elfving. Helsingfors, Finland.
1901. Professor H. Elster, Wolfenbüttel, Germany.
1894. Professor T. W. W. Engelmann, D.C.L. Neue Wilhelmstrasse 15, Berlin, N.W.
1892. Professor Léo Errera. 38 Rue de la Loi, Brussels.
1901. Professor W. G. Farlow. Harvard, U.S.A.
1874. Dr. W. Feddersen. Carolinenstrasse 9, Leipzig.
1886. Dr. Otto Finsch. Leiden, Netherlands.
1887. Professor Dr. R. Fittig. Strassburg.
1894. Professor Wilhelm Foerster, D.C.L. Encke Platz 3A, Berlin, S.W. 48.
1872. W. de Fonvielle. 50 Rue des Abbesses, Paris.
1901. Professor A. P. N. Franchimont. Leiden.
1894. Professor Léon Fredericq. Rue de Pitteurs 20, Liége, Belgium.
1887. Professor Dr. Anton Fritsch. 66 Wenzelsplatz, Prague, Bohemia.
1892. Professor Dr. Gustav Fritsch. Dorotheen Strasse 35, Berlin.
1881. Professor C. M. Gariel. 6 rue Edouard Détaille, Paris.
1866. Dr. Gaudry. 7 bis rue des Saints Pères, Paris.
1901. Professor Dr. Geitel, Wolfenbüttel, Germany.
1884. Professor J. Willard Gibbs. Yale University, New Haven, Conn., U.S.A.
1884. Professor Wolcott Gibbs. Newport, Rhode Island, U.S.A.
1889. G. K. Gilbert. United States Geological Survey, Washington, D.C., U.S.A.
1892. Daniel C. Gilman. Johns Hopkins University, Baltimore, U.S.A.
1870. William Gilpin. Denver, Colorado, U.S.A.
1889. Professor Gustave Gilson. l'Université, Louvain, Belgium.
1889. A. Gobert. 222 Chaussée de Charleroi, Brussels.
1884. General A. W. Greely, LL.D. War Department, Washington, U.S.A.
1892. Dr. C. E. Guillaume. Bureau International des Poids et Mesures, Pavillon de Breteuil, Sèvres.
1876. Professor Ernst Haeckel. Jena.
1881. Dr. Edwin H. Hall. 37 Gorham-street, Cambridge, Mass., U.S.A.
1895. Professor Dr. Emil Chr. Hansen. Carlsberg Laboratorium, Copenhagen, Denmark.
1887. Fr. von Hefner-Alteneck. Berlin.
1893. Professor Paul Heger. Rue de Drapiers 23, Brussels.
1894. Professor Ludimar Hermann. Universität, Königsberg, Prussia.
1893. Professor Richard Hertwig. Zoologisches Institut, Alte Akademie, Munich.
1893. Professor Hildebrand. Stockholm.
1897. Dr. G. W. Hill. West Nyack, N.Y., U.S.A.
1887. Professor W. His. Königstrasse 22, Leipzig.
1881. Professor A. A. W. Hubrecht, LL.D., C.M.Z.S. The University, Utrecht, Netherlands.
1887. Dr. Oliver W. Huntington. Cloyne House, Newport, R. I., U.S.A.
1884. Professor C. Loring Jackson. 6 Boylston Hall, Cambridge, Massachusetts, U.S.A.
1867. Dr. J. Janssen, LL.D. L'Observatoire, Meudon, Seine-et-Oise.
1876. Dr. W. J. Janssen. Villa Frisia, Aroza, Graubünden, Switzerland.
1881. W. Woolsey Johnson, Professor of Mathematics in the United States Naval Academy. 32 East Preston Street, Baltimore, U.S.A.

Year of
Election.

1887. Professor C. Julin. 153 rue de Fragnée, Liége.
1876. Dr. Giuseppe Jung. 9 Via Borgonuovo, Milan.
1884. Professor Dairoku Kikuchi, M.A. Imperial University, Tōkyō, Japan.
1873. Professor Dr. Felix Klein. Wilhelm-Weberstrasse 3, Göttingen.
1894. Professor Dr. L. Kny. Kaiser-Allee 92, Wilmersdorf, bei Berlin.
1896. Dr. Kohlrausch. Marchstrasse 25B, and Physikalisch-technische Reichsanstalt, Charlottenburg, Berlin.
1856. Professor A. von Kölliker. Würzburg, Bavaria.
1894. Professor J. Kollmann. St. Johann 88, Basel, Switzerland.
1887. Professor Dr. Arthur König. Physiological Institute, The University, Berlin, N.W.
1894. Maxime Kovalevsky. Beaulieu-sur-Mer, Alpes-Maritimes.
1887. Professor W. Krause. Knesebeckstrasse, 17/I, Charlottenburg, bei Berlin.
1877. Dr. Hugo Kronecker, Professor of Physiology. Universität, Bern, Switzerland.
1887. Professor A. Ladenburg. Kaiser Wilhelm Str. 108, Breslau.
1887. Professor J. W. Langley. 77 Cornell Street, Cleveland, Ohio, U.S.A.
1882. Dr. S. P. Langley, D.C.L., Secretary of the Smithsonian Institution. Washington, U.S.A.
1887. Dr. Leeds, Professor of Chemistry at the Stevens Institute, Hoboken, New Jersey, U.S.A.
1872. M. Georges Lemoine. 76 Rue Notre Dame des Changes, Paris.
1901. Professor Philipp. Lenard, Kiel.
1887. Professor A. Lieben. IX. Wasagasse 9, Vienna.
1883. Dr. F. Lindemann. Franz-Josefstrasse 12/I, Munich.
1877. Dr. M. Lindemann. Sennorrstrasse 62, II, Dresden.
1887. Professor Dr. Georg Lunge. Universität, Zurich.
1871. Professor Jacob Lüroth. Mozartstrasse 10, and Universität, Freiburg-in-Breisgau, Germany.
1894. Dr. Otto Maas. Wurzerstrasse 1b, Munich.
1887. Dr. Henry C. McCook. 3,700 Chestnut-street, Philadelphia, U.S.A.
1867. Professor Mannheim. 1 Boulevard Beauséjour, Paris.
1887. Dr. C. A. Martius. Voss Strasse 8, Berlin, W.
1890. Professor E. Mascart, Membre de l'Institut. 176 rue de l'Université, Paris.
1887. Professor D. I. Mendeléeff, D.C.L. Université, St. Petersburg.
1887. Professor N. Menschutkin. St. Petersburg.
1884. Professor Albert A. Michelson. The University, Chicago, U.S.A.
1887. Dr. Charles Sedgwick Minot. Boston, Massachusetts, U.S.A.
1894. Professor G. Mittag-Leffler. Djuvsholm, Stockholm.
1893. Professor H. Moissan. The Sorbonne, Paris (7 Rue Vauquelin).
1877. Professor V. L. Moissenet. 4 Boulevard Gambetta, Chaumont, Hte. Marne, France.
1894. Dr. Edmund von Mojsisovics. Strohgasse 26, Vienna, III/3.
1897. Professor Oskar Montelius. St. Paulsgatan 11, Stockholm, Sweden.
1864. Dr. Arnold Moritz. The University, Dorpat, Russia.
1897. Professor E. W. Morley, LL.D. Adelbert College, Cleveland, Ohio, U.S.A.
1887. E. S. Morse. Peabody Academy of Science, Salem, Mass., U.S.A.
1889. Dr. F. Nansen. Lysaker, Norway.
1894. Professor R. Nasini. Istituto Chimico dell' Università, Padova, Italy.
1864. Dr. G. Neumayer. Deutsche Seewarte, Hamburg.
1884. Professor Simon Newcomb. 1620 P.-street, Washington, D.C. U.S.A.

Year of Election.

1887. Professor Emilio Noelting. Mühlhausen, Elsass, Germany.
1894. Professor H. F. Osborn. Columbia College, New York, U.S.A.
1894. Baron Osten-Sacken. Heidelberg.
1890. Professor W. Ostwald. Linnéstrasse 2, Leipzig.
1889. Professor A. S. Packard. Brown University, Providence, Rhode Island, U.S.A.
1890. Maffeo Pantaleoni. 20 Route de Malagnou, Geneva.
1895. Professor F. Paschen. Universität, Tübingen.
1887. Dr. Pauli. Feldbergstrasse 49, Frankfurt a. M., Germany.
1901. Professor A. Penck. Vienna.
1890. Professor Otto Pettersson. Stockhoms Hogskola, Stockholm.
1894. Professor W. Pfeffer, D.C.L. Linnéstrasse 11, Leipzig.
1870. Professor Felix Plateau. 152 Chaussée de Courtrai, Gand, Belgium.
1884. Major J. W. Powell, Director of the Geological Survey of the United States. 1333 F. Street, N.W., Washington, D.C., U.S.A.
1886. Professor F. W. Putnam. Harvard University, Cambridge, Massachusetts, U.S.A.
1887. Professor Georg Quincke. Hauptstrasse 47, Friederichsbau, Heidelberg.
1868. L. Radlkofer, Professor of Botany in the University of Munich. Sonnenstrasse 7.
1895. Professor Ira Remsen. Johns Hopkins University, Baltimore, U.S.A.
1886. Rev. A. Renard. 6 Rue du Roger, Gand, Belgium.
1897. Professor Dr. C. Richet. 15 Rue de l'Universitó, Paris, France.
1873. Professor Baron von Richthofen. Kurfürstenstrasse 117, Berlin, W.
1896. Dr. van Rijckevorsel. Parklaan 7, Rotterdam, Netherlands.
1892. Professor Rosenthal, M.D. Erlangen, Bavaria.
1890. A. Lawrence Rotch. Blue Hill Observatory, Readville, Massachusetts, U.S.A.
1895. Professssr Karl Runge. Kaiser Wilhelmstrasse 5, Kirchrode, bei Hannover.
1901. Gen.-Major Rykatchew. St. Petersburg.
1894. Professor P. H. Schoute. The University, Groningen, Netherlands.
1883. Dr. Ernst Schröder. Gottesanerstrasse 9, Karlsruhe in Baden.
1874. Dr. G. Schweinfurth. Potsdamerstrasse 75A, Berlin.
1897. Professor W. B. Scott. Princeton, N.J., U.S.A.
1873. Dr. A. Shafarik. Vinohrady 422, Prague.
1892. Dr. Maurits Snellen, Chief Director of the Royal Meteorological Institute of the Netherlands, de Bilt, near Utrecht.
1887. Professor H. Graf Solms. Bot. Garten, Strassburg.
1887. Ernest Solvay. 25 Rue du Prince Albert, Brussels.
1888. Dr. Alfred Springer. 312 East 2nd St., Cincinnati, Ohio, U.S.A.
1889. Professor G. Stefanescu. Strada Verde 8, Bucharest, Roumania.
1881. Dr. Cyparissos Stephanos. The University, Athens.
1894. Professor E. Strasburger. The University, Bonn.
1881. Professor Dr. Rudolf Sturm. Fränkelplatz 9, Breslau.
1884. Professor Robert H. Thurston. Cornell University, Ithaca, New York, U.S.A.
1887. Dr. T. M. Treub. Buitenzorg, Java.
1887. Professor John Trowbridge. Harvard University, Cambridge, Massachusetts, U.S.A.
Arminius Vámbéry, Professor of Oriental Languages in the University of Pesth, Hungary.
1890. Professor Dr. J. H. van't Hoff Uhlandstrasse 2, Charlottenburg, Berlin.
1889. Wladimir Vernadsky. Mineralogical Museum, Moscow.

Y

Election.

1886. Professor Jules Vuylsteke. 21 rue Belliard, Brussels, Belgium.

1887. Professor H. F. Weber. Zurich.

1887. Professor Dr. Leonhard Weber. Moltke Strasse 60, Kiel.

1887. Professor August Weismann. Freiburg-in-Breisgau, Baden.

1887. Dr. H. C. White. Athens, Georgia, U.S.A.

1881. Professor H. M. Whitney. Branford, Conn., U.S.A.

1887. Professor E. Wiedemann. Erlangen. [C/o T. A. Barth, Johannisgasse, Leipzig.]

1887. Professor Dr. R. Wiedersheim. Hansastrasse 3, Freiburg-im-Breisgau, Baden.

1887. Professor Dr. J. Wislicenus. Liebigstrasse 18, Leipzig.

1887. Dr. Otto N. Witt. 21 Siegmundshof, Berlin, N.W. 23.

1876. Professor Adolph Wüllner. Aureliusstrasse 9, Aachen.

1887. Professor C. A. Young. Princeton College, New Jersey, U.S.A.

1896. Professor E. Zacharias. Botanischer Garten, Hamburg.

1887. Professor F. Zirkel. Thalstrasse 33, Leipzig.

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Dublin, Geological Survey of Ireland.
——, Royal College of Surgeons in Ireland.
——, Royal Geological Society of Ireland.
——, Royal Irish Academy.
——, Royal Society of.
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Canterbury Museum.

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